FINAL REPORT

Smart Water Conservation System for Irrigated Landscape

ESTCP Project EW-201019

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14. ABSTRACT

The DoD has numerous facilities that use inefficient irrigation processes (timer based and manual watering systems) that are no longer sustainable given the limited water supplies in many U.S. locations and future water demand. Smart water conservation systems may provide DoD a pathway for preserving green landscape assets while simultaneously reducing potable water demand for landscape irrigation. This project demonstrated the retrofit of a typical DoD building with an integrated suite of commercially available water conservation technologies designed to reduce potable water usage. Specific technologies tested include: evapotranspiration irrigation controller; centralized and site-specific sensor inputs such as ET gauge, rain, soil moisture, leak detection; efficient water delivery systems and roof top rainwater and HVAC condensate harvesting systems to displace potable water used for irrigation. This report documents demonstration results for a smart water conservation system implemented at a large administrative building located at Naval Base Ventura County, California. The smart water system achieved an 81% reduction in potable water use when two similar plots of turf, one using "smart" irrigation practices and the other using traditional timer, were compared.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

BMP	best management practice
CERL	Construction Engineering Research Laboratory
DoD	Department of Defense
DOE	Department of Energy
EISA	Energy Independence and Security Act
EO	Executive Order
ESTCP	Environmental Security Technology Certification Program
ET	evapotranspiration
FEMP	Federal Energy Management Program
FY	fiscal year
gph	gallons per hour
gpm	gallons per minute
HVAC	heating, ventilation and air conditioning
ILA	industrial, landscaping, and agricultural
LEED	Leadership in Energy and Environmental Design
mph	miles per hour
MTBF	mean time between failures
MTTF	mean time to failure
MWDSC	Metropolitan Water District of Southern California
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBVC	Naval Base Ventura County
NCBC	Naval Construction Battalion Center
NIST	National Institute of Standards and Technology
NMCI	Navy Marine Corps Intranet
PLC	programmable logic controller
psi	pounds per square inch
SIR	Savings to Investment Ratio
SMS	soil moisture sensor
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	underground storage tank

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EXECUTIVE SUMMARY

From January 2013 through January 2015 the U.S. Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) sponsored the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) and the Construction Engineering Research Laboratory (CERL) in a joint effort to demonstrate a smart water conservation system that reduces the volume of potable water required for landscape irrigation. A suite of specific water saving technologies was demonstrated including: evapotranspiration (ET) irrigation controller; centralized and site-specific sensor inputs (ET gauge, rain, soil moisture, leak detection); efficient sprinkler distribution systems; and water harvesting (rain and air conditioning condensate).

The DoD has numerous facilities that use inefficient irrigation practices (timer based and manual watering systems) that are no longer sustainable given the limited water supplies in many U.S. locations and future water demand. Executive Order (EO) 13693 requires the Federal government to reduce potable water usage 36% by 2025. The smart water conservation system may provide DoD a pathway to preserve green landscape assets while simultaneously reducing potable water demand for landscape irrigation, hence complying with the EO. In addition, to move forward with greater energy independence, the DoD seeks ways to reduce energy use as required by the Energy Independence and Security Act (EISA). Reducing potable water demand for landscape irrigation correlates to lower energy costs necessary to treat and convey water to DoD facilities.

The primary project objective was to validate the retrofit of an existing landscape irrigation system with a smart water conservation system to reduce potable water use by as much as 70% in support of meeting EO 13693. Additional performance objectives were to validate energy reduction, cost effectiveness, and system reliability while maintaining satisfactory plant health. This report provides potential users with cost and performance data for using the smart system components on an existing landscape and on new developments.

The demonstration was conducted for two different climatic regions in the southwestern part of the United States, where a typical DoD building landscape irrigation system was retrofitted with an integrated suite of commercially available water conservation technologies designed to decrease potable water usage. The demonstration sites were Naval Base Ventura County (NBVC) Port Hueneme, California and Fort Hood, Killeen, Texas.

The project was performed on two similar turf plots, one using "smart" irrigation practices (smart plot) and the other using traditional timer based irrigation (control plot). Specific success metrics were established to compare potable water use, energy use, operating cost, economic payback, irrigation effectiveness and qualitative turf health (appearance) for the smart and control plots. The selected smart and control turf plot areas had similar initial landscape, plant health, plot size, microclimate, sun/wind exposure and usage/traffic so that an equitable comparison could be made over a two year monitoring period.

The irrigation systems at both demonstration sites were outfitted with flow meters at various locations to track the volume of potable irrigation water delivered to the smart and control plots,

as well as the volume of rain and HVAC condensate water harvested by the smart irrigation system. Volume data was collected monthly and at the end of the two years totaled to assess overall and individual performance of the system.

Unfortunately, significant equipment failures and instrumentation issues at the Fort Hood demonstration site resulted in data gaps that prevented adequate assessment of the technology. This final report focuses on findings from the NBVC Port Hueneme demonstration, but includes key information and lessons learned from the Fort Hood demonstration that are provided in the appendices.

The following performance metrics were obtained from the two year demonstration at NBVC site:

- The smart water system as a whole reduced potable water use by 81%
- The evapotranspiration controller's contribution towards water reduction was 55%
- Overall energy usage was reduced by 57.4%
- All smart water system components achieved 100% operational availability during the monitoring phase.
- At the conclusion of the monitoring phase, turf specialists from California State University, Fresno determined the appearance of the smart plot was slightly less than the control plot but still considered satisfactory.
- The performance objective for economic payback set at 25 years was not achieved. The primary reason was the high cost to install the harvest tank and the relatively small size of the smart plot
- The economic payback for the retrofitted ET controller was 2 years.
- The calculated economic pay back for a new ET controller installation (without condensate and rainwater harvesting) was 5.2 years.

The smart water conservation system at NBVC met primary water reduction goals and all of the additional performance objectives with the exception of economic payback. The system did not meet the economic payback period due to the high cost of the water harvest tank, relatively low cost of potable water, and relatively small size of the smart turf plot. However, as the amount of irrigated landscape is increased, and/ or the cost of water increases, the payback period will trend to a more favorable figure due to the substantial water reduction provided by the ET controller.

The downside is as the size of the irrigated landscape increases for a given tank size, the overall water reduction will trend lower towards the 55% reduction demonstrated by ET controller, thus reducing the value of the harvested water. Offsetting potable water with rain water to irrigate turf landscape at the NBVC site, where there is minimal to no summer rain, would require a larger tank (over 20,000 gallons) to store winter rain. In southern California, the goal is to install the largest tank possible to meet summer irrigation requirements. However, the economics do not indicate that there is a reasonable return on investment.

The ideal geographic areas to implement a smart water conservation system are locations such as Tucson, Arizona and Fort Hood, Texas which receive summer monsoonal rains that replenish the water harvest tank during the summer months when demand is greatest. In addition, facilities in these locations are also known to generate large amounts of air conditioning condensate. Areas that have high local water costs or limited water supply options may also benefit from water harvest.

Economic payback and water reduction potential is determined on a case by case basis with consideration for site specific factors including local water cost, irrigation demand, roof size and water harvesting tank size. If current tank capital costs were held at $3.13 per gallon, then potable water costs would have to be $34 per 1,000 gallon to meet the 20-year performance objective

EXWC has developed an excel economic spreadsheet to calculate overall water reduction and payback for potential end users to assist in evaluating system cost effectiveness based on site conditions. The spreadsheet is available to federal activities to assist potential users determine when it is appropriate to install the entire smart water system or simply components such as the smart ET controller alone. The chart assumes a Mediterranean climate, and water cost similar of Port Hueneme area and tank cost of $3.98 per gallon of storage.

1.0 INTRODUCTION

From January 2013 through January 2015 the U.S. Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) sponsored the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) in collaboration with the Construction Engineering Research Laboratory (CERL) to demonstrate a smart water conservation system for landscape irrigation. The demonstration was conducted at two different climatic regions in the southwestern part of the United States, where the typical DoD building landscape irrigation system was retrofitted with an integrated suite of commercially available water conservation technologies designed to reduce potable water usage. The demonstration sites were Naval Base Ventura County (NBVC) Port Hueneme, California, and Fort Hood, Killeen, Texas.

- The primary project objectives were to; 1) demonstrate the feasibility of retrofitting an existing, traditional landscape irrigation system with a smart water conservation system that uses water harvesting and real-time weather data to optimize irrigation scheduling and 2) validate the smart water conservation system's ability to reduce both potable and overall water consumption for irrigation at our DoD installations located in semi-arid regions where alternative water conservation measures are being pursued.

The demonstration project compared two turf areas with contrasting irrigation practices (smart and control) that had similar initial landscape, plant health, plot size, microclimate, sun/wind exposure and usage/traffic. The primary metrics used to evaluate irrigation system performance were potable water use, operating cost, energy use, irrigation effectiveness, and plant health.

- Unfortunately, significant instrumentation issues at the Fort Hood demonstration site resulted in unreliable data that prevented adequate assessment of the technology. This report focuses on findings from the NBVC Port Hueneme demonstration site, but includes key information and lessons learned from Fort Hood provided in Sections 2, 3 and 8 and Appendix J.

1.1 Background

The DoD operates numerous facilities in the southwestern U.S. that utilize irrigation systems and practices which are highly inefficient and no longer sustainable given current water supplies and projected future water demand. DoD facilities located within this region and their respective mission are particularly impacted by this decreasing water supply and quality (e.g., salinity issues), increasing cost of water production, and degradation of ecological habitat, with these issues anticipated to intensify into the future.

In addition, the Federal Energy Management Program (FEMP) of the Department of Energy (DOE) estimates that the Federal Government used approximately 164 billion gallons of potable water in fiscal year (FY) 2007 (Annual Report to Congress on Federal Government Energy Management and Conservation Programs: FY 2007 FEMP, January 2010). The DoD consumed 117 billion gallons of water, representing 71.1% of the Federal Government water consumption at an annual cost of $359M.

Overall, DoD facilities use significant volumes of potable water to irrigate large turf areas (e.g., athletic fields, parade grounds, and housing landscape) for recreational, aesthetic, and morale purposes. In certain cases, potable water consumption for irrigated landscape surrounding DoD buildings is equivalent to two to five times the internal water consumption of the building. In addition, the United States Environmental Protection Agency (U.S. EPA) estimates that more than 50% of this water used for irrigating landscape is then lost to evaporation, wind, and overwatering.

As such, current irrigation practices at many DoD facilities may require upgrades with innovative, smart irrigation systems that can be integrated with existing infrastructure and operated in a manner to reduce water consumption and operating cost. As part of this project, a smart water conservation system for irrigated landscapes with several features, including weather-based irrigation controllers, centralized and site-specific sensor inputs, leak detection sensors, and the use of harvested water (i.e., rainwater and air condition water condensate), was demonstrated to determine its effectiveness in reducing water consumption, decreasing operating costs, and maintaining landscape compared to a traditional irrigation system.

1.2 Objective of the Demonstration

The primary objectives of this project were to:

1. Demonstrate the feasibility of retrofitting an existing, traditional landscape irrigation system with smart water conservation technologies; and
2. Demonstrate the effectiveness of the smart water conservation technologies in reducing water consumption, decreasing operating costs, and maintaining landscape compared to the traditional landscape irrigation system (timer based irrigation).

The overarching objectives of the field demonstration were to:

1. Reduce water consumption (particularly potable water consumption) used for irrigation;
2. Reduce associated potable water and operating costs;
3. Determine the payback period for implementation of smart water conservation technologies (as a system and individual components); and
4. Maintain an acceptable quality of landscape turf and flora for aesthetic purposes.

1.3 Regulatory Drivers

- An appreciable amount of water use in the U.S. is for irrigation purposes (i.e., at 33%; U.S. Geological Survey [USGS], 2014); therefore, the results of this demonstration project may provide a mechanism for DoD facilities to more easily meet regulatory requirements for water conservation and sustainability enforced at the federal, state, and installation level.

- Executive Order (EO) 13693, *Planning for Federal Sustainability in the Next Decade*, was released on March 25, 2015 and expands upon, but also revokes, previous EOs 13514 and 13423, which outline sustainability goals for federal agencies (e.g., DoD). As such, EO 13693 serves as the current federal regulatory driver for this demonstration project and requires agencies to improve water use efficiency and management, as follows:
    i. Reducing agency potable water consumption intensity measured in gallons per gross square foot by 36% by fiscal year (FY) 2025 through reductions of 2% annually through FY 2025 relative to a baseline of the agency's water consumption in FY 2007;
    ii. Installing water meters and collecting and utilizing building and facility water balance data to improve water conservation and management;
    iii. Reducing agency industrial, landscaping, and agricultural (ILA) water consumption measured in gallons by 2% annually through FY 2025 relative to a baseline of the agency's ILA water consumption in FY 2010; and
    iv. Installing appropriate green infrastructure features on federally-owned property to help with stormwater and wastewater management.

Additionally, drought conditions have persisted within the southwestern U.S., requiring states, particularly California, to establish mandates for reductions in water usage. On April 1, 2015, Governor Brown of California signed EO B-29-15 into law, proclaiming a Continued State of Emergency throughout the state due to the ongoing drought. The EO imposes restrictions to achieve a statewide 25% reduction in potable urban water usage through February 28, 2016 compared to the amount used in 2013.

Due to these drought conditions in California, the Commanding General at Marine Corps Air Ground Combat Center Twentynine Palms also released a Water Conservation Policy, which establishes specific water-saving measures and leads all efforts to ensure the conservation and sustainability of its water resources and ultimately, the mission of the Marine Corps into the future. Measures include using hoses with shut off nozzles, insuring that outdoor watering does not cause runoff to adjacent property sidewalks, parking lots or structures and elimination of potable water used on fountains and decorative water features.

Overall, implementation of a smart water conservation technology for landscape irrigation may assist DoD facilities in meeting the water sustainability goals outlined in EO 13693, specifically reducing potable water consumption intensity, reducing ILA water consumption, and installing appropriate green infrastructure, as well as meeting any state or installation level requirements.

For new development or redevelopment projects, implementation of water harvesting cisterns supports compliance with Section 438 of the Energy Independence and Security Act (EISA) of 2007, requiring federal facilities to reduce runoff to protect water resources. Section 438 specifically calls for developments that exceed 5,000 square feet to maintain pre-development hydrology by retaining water on-site. Federal activities can comply using a variety of green infrastructures including the use of "low impact development" practices such a water harvesting with cisterns to retain and reuse water. Activities have two options to demonstrate compliance of

predevelopment hydrology: managing on-site the total volume of rainfall from the 95^{th} percentile storm or managing the total storm based on site specific hydrologic analysis. Implementation of a smart water conservation system, specifically the water harvesting components can help activities meet pre-development hydrology requirements.

2.0 TECHNOLOGY DESCRIPTION

2.1 Technology Overview

The smart water conservation system demonstrated during this project was composed of an integrated suite of commercially available technologies for irrigating landscape (i.e., turf and low-water demand ground cover). The primary system components selected for this study are described in further detail in Section 5.3.

1. Advanced evapotranspiration (ET) controller to reduce potable water usage by minimizing operating times (calculates run time based on real time weather conditions). System includes the following components:
    - Soil moisture sensor – shuts down irrigation once optimum soil moisture is reached
    - Rain gauge – shuts down irrigation on rainy days
    - ET gauge – estimates daily water loss from plant and land surfaces
    - Leak flow sensors – shuts down irrigation if a pipe/sprinkler ruptures
2. Rainwater and HVAC condensate water harvesting system components:
    - Pipeline collection system
    - First flush diverter
    - Underground storage tank (UST) for harvested water
    - Pumping and float switch system
3. Irrigation hardware:
    - Efficient sprinkler heads – to provide uniform coverage and prevent misting/overspray
    - Pressure regulating valves – to ensure optimum nozzle pressure and prevent misting/overspray

The rainwater harvesting system is comprised of off-the shelf plumbing and tank components including a first flush diverter that redirects the first part of a rain event, which normally contains the greatest concentration of pollutants, away from the harvest tank. The “first flush” contains contaminants such as bird droppings and suspended solids that can clog sprinkler components, thereby reducing irrigation efficiency and increasing maintenance requirements. It is better to remove the debris prior to entering the tank, and conventional design guidance suggests diverting 1 liter per square meter roofing for lightly loaded roofs and 2 liters per square meter for heavier loads. Appendix A provides manufacturer specifications and general schematics for the first flush diverter and other system components that were tested during the demonstration.

The resultant harvested rainwater and HVAC system condensate water is used to irrigate a portion of the landscape via an advanced ET controller system, integrated with a pump and a water efficient sprinkler system. The advanced ET controller used at the Port Hueneme Demonstration site was the Calsense 2000E smart irrigation modular controller, developed by the Calsense

Corporation. It is a programmable logic controller (PLC) capable of configuring up to 32 stations, while providing numerous flexible programming options and self-diagnostic feedback to identify field wiring, sensor input, and solenoid problems during operation. One goal of this project was to demonstrate the controller's ability to efficiently manage landscape irrigation by using real-time data and multiple water sources to minimize the volume of potable water required to supplement landscape irrigation.

The Calsense controller uses real-time weather data via radio signals broadcasted or hardwired from local weather stations and site-specific soil and rain sensor inputs to adjust watering schedules. The system allows remote control of the system via personal computer, and includes remote features such as manual operation, program adjustment, along with dial and switch settings. These features can potentially provide substantial travel savings by allowing routine irrigation programming modification and, in some cases, more complicated troubleshooting to be conducted remotely.

The advanced controller used at the Fort Hood demonstration site used a soil moisture sensor and the Baseline 3200 irrigation controller, developed by Baseline Incorporated. The controller is capable of configuring up to 200 zones while providing numerous flexible programming options and self-diagnostic feedback to identify field wiring, sensor input, and solenoid problems during operation. In lieu of direct ET data to adjust the irrigation schedule, the Baseline 3200 controller uses the soil moisture sensor to adjust water schedule by measuring the effect of evapotranspiration in the root zone using a relative measure of soil moisture captured at 6" below the soil surface. The controller can be configured to keep the soil moisture at user defined levels for maintaining optimum plant health, and kept below field capacity. Keeping the soil moisture below field capacity reduces water waste by minimizing excess runoff or drainage. Similar to the Calsense controller this effort was to demonstrate the controller's ability to efficiently manage landscape irrigation by using real-time data and multiple water sources to minimize the volume of potable water required to supplement landscape irrigation.

When combined with efficient irrigation hardware and water harvesting, the advanced controller technologies provide an innovative method to reduce the amount of potable water used for irrigation purposes by up to 70%. Figure 1 presents a schematic diagram of the smart water conservation system (including all components) as well as the traditional irrigation system (i.e., control plot) that was evaluated at Port Hueneme, California.

2.2 Technology Development

The smart water conservation system was devised from existing sensor and water harvesting technologies developed in agriculture and turf industries. Rainwater has been harvested for centuries from the roofs of buildings, and condensate water is currently being harvested and used for irrigation at several large institutions on the east coast. The rainwater and HVAC condensate are advantageous water sources because they require no pre-treatment (other than a first flush diverter) and can be inexpensively harvested and applied to landscape irrigation. The sensor technologies have been used and extensively tested in the last 20 years by reputable universities across the United States.

A study conducted by Cardenas Lailhacar et al. (2010) in Florida compared the water usage of Bermuda grass plots with traditional timer-based systems, timer-based systems with rain sensors, and systems with soil moisture sensors. The traditional systems and the systems with rain sensors were watered twice a week, and the soil-moisture sensor based system was tested watering once, twice, and seven days a week. A control plot that received no irrigation was also included in the study. The systems with rain sensors reduced water usage 13-24%, and the systems with soil-moisture sensors reduced water usage 16-83%.

A study conducted in the mid-1990s in Boulder, Colorado evaluated maintenance requirements for soil moisture sensors in urban settings. Of 23 sensors in service at least three years, only two failed during the study. The effort to maintain the system was estimated to be approximately 6 to 7 minutes per weekly visit.

In addition to these studies conducted in Florida and Colorado, many studies have been conducted in California – the location of this demonstration project. The Pacific Institute (pacinst.org) summarizes seven studies conducted on farms in California that demonstrate activities that: 1) lead to more efficient applied water use or enhance water quality; 2) increased crop yields or quality; and 3) provided multiple benefits (Christian-Smith et al., 2010). Overall, the majority of studies indicate that soil moisture sensor systems can significantly reduce water usage without sacrificing the quality of the crops, as long as the sensors are installed correctly and settings are optimal for the crops based on site conditions, such as soil and plant type.

A variety of commercially available first flush diverters can be used in rainwater harvest systems. The three diverters initially used at the Port Hueneme demonstration site were developed by the Australian company SafeRain and incorporate a flow rate based diversion valve design. In addition, a constant volume diverter was incorporated into the evaluation. During the demonstration period it was discovered that the flow rate-based diversion valve required substantial maintenance after every storm event to fully drain the diverter valve body and reset the device for subsequent storm events. After some minor adjustments, the problem still was not resolved. NAVFAC EXWC constructed a new constant volume diverter to replace one of the flow based diversion valves to address the reset issue. The constant volume diverter, which is a variation of an existing design, required minimal maintenance and reset itself for the next storm event without intervention, as observed during the rest of the demonstration. The design is simple and can be made with commercially available products. Figure 9 in Section 5.3.2 displays a picture of both first flush designs. Appendix A provides greater detail for each diverter design.

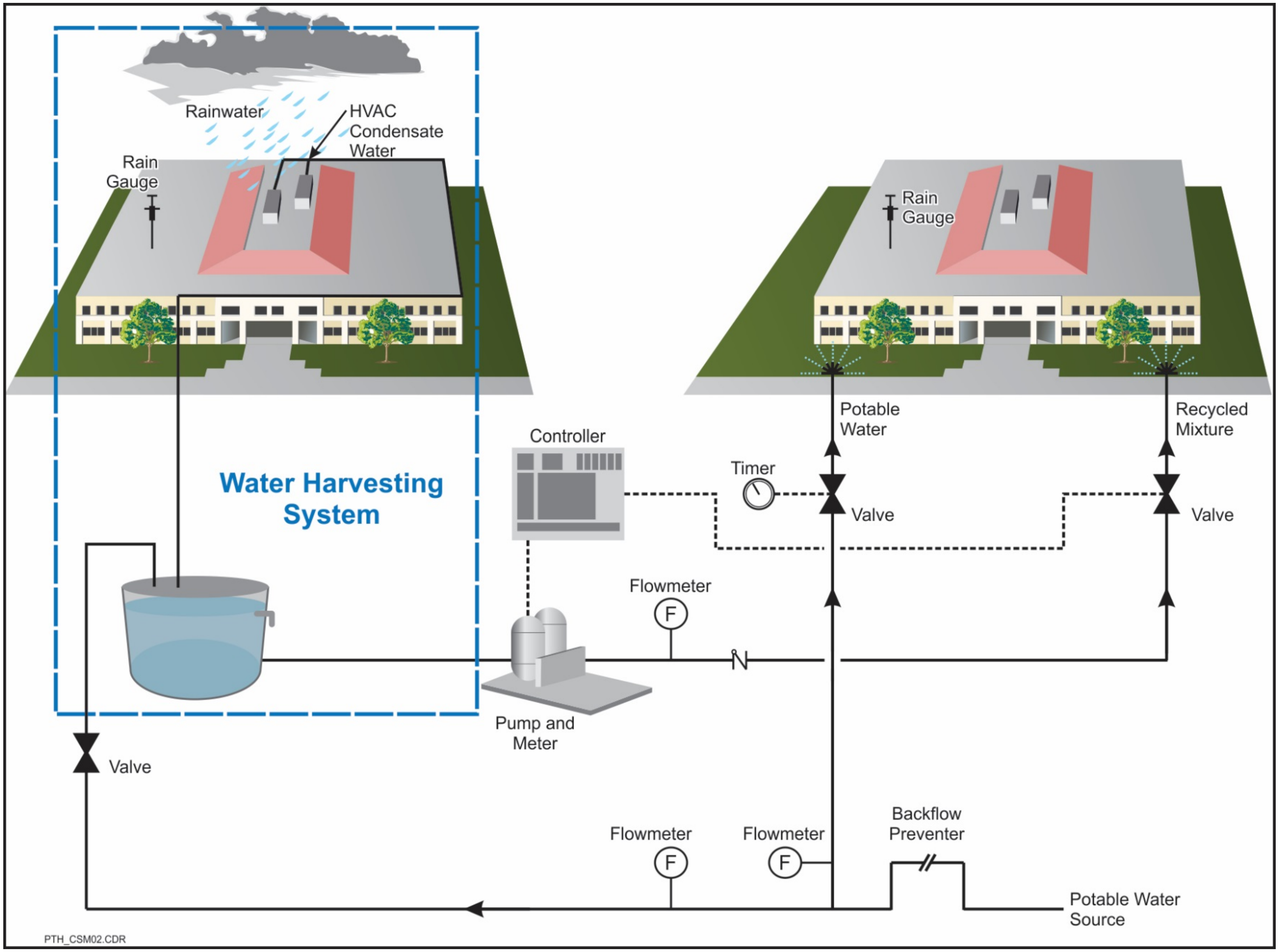

Figure 1. Schematic Diagram of the Smart Water Conservation System and Traditional Irrigation System

2.3 Advantages and Limitations of the Technology

The primary advantages of implementing the smart water conservation system over a traditional irrigation system are: 1) the conservation of potable water resources; and 2) the cost savings associated with reducing potable water use. Specific technical advantages of the smart water conservation system compared to a traditional irrigation system are provided in Table 1.

Table 1. Advantages and Limitations of Selected Irrigation Systems

Irrigation System	Advantages	Limitations
Smart Water Conservation System	• Uses harvested water to offset the use of potable water; potable water is only used if necessary to supplement the volume of water required for irrigation. Less water used results in reduced energy usage. • Controller collects and evaluates real-time sensor data to determine when it is necessary to irrigate and how much water to apply based on site conditions. • Provides remote access to the controller which allows operators to modify certain operational settings of the system without being present at the site. • Equipped with high-efficiency volume sprinkler nozzles and pressure regulating devices to achieve a more uniform distribution of water throughout the landscape. • Supports compliance with EO 13693.	• HVAC condensate from rooftops can be easily routed to above or below-grade tanks using gravity, whereas floor-level HVAC systems may require pumping systems. The added cost to install and maintain a pumping system can negatively impact feasibility. • Condensate collection systems for large buildings with decentralized/multiple HVAC units can be expensive to plumb, which can negatively impact feasibility. For buildings with multiple HVAC units, it is best to draw condensate water from those that chill outside air and are nearest to the water harvest tank. Units that chill outside air will provide more condensate water than those units that intake re-circulated indoor air. • Application in an extremely arid climate is limited to non-turf landscape and small areas of turf. The volume of water needed to support a substantive turf area in an arid climate is exorbitantly high and not considered sustainable. • HVAC condensate may not be practical in a semi-arid climate, where indoor air is mostly re-circulated, and HVAC unit temperature set points are intentionally high to conserve energy.
Traditional Irrigation System	• May be applicable in any climate (i.e., arid and/or semi-arid). • Are economical in many regions of the country where potable water is inexpensive.	• Rely entirely on potable water. • Timer-based and will operate whenever programmed to, regardless of whether irrigation is necessary. Typically, timer-based systems are adjusted higher than needed to account for consecutive hot days that stress turf beyond the wilting point. • Require personnel to be onsite to make adjustments to the watering schedule. • Do not provide high-efficiency irrigation hardware.

3.0 PERFORMANCE OBJECTIVES

The primary success criteria for the smart water conservation system was to reduce potable water usage for landscape irrigation by 70%, while maintaining or increasing landscape condition. Table 2 summarizes all the established quantitative and qualitative performance objectives, their respective success criteria for determining progress towards meeting the goals, and the final results.

Table 2. Summary of Quantitative and Qualitative Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Reduction of potable water usage	Amount of potable water used for irrigation (gal)	• Metered water usage • Historic metered water usage	> 70% reduction in potable water use	Achieved 81%
Reduction of potable water costs	Water and electrical costs	• Metered water usage • Historic metered water usage • Current and historic water rates/costs • Calculated electrical usage • Current and historic electrical costs • Hours of pump operation	> 50% reduction in potable water cost	Achieved 81%
Economic payback period	Cost savings from smart water conservation system	• Capital equipment costs • Electrical costs • Water costs	≤ 20 years	Not Achieved 53 years
Savings to Investment Ratio (SIR)			SIR >1.0	Not Achieved 0.53
Overall energy use reduction	Pumping costs per amount of water used for irrigation	• Metered water usage • Historic metered water usage • Calculated electrical usage • Historic metered electrical usage • Hours of pump operation	> 40 % reduction in energy	Achieved 57.4%
System Availability	Time system is operational	• Downtime, Uptime • Number of failures • Time to repair • Mean Time Between Failure • Mean Time To Failure • Maintenance and repair logs	> 95% Availability	Achieved 98%

Table 2. Summary of Quantitative and Qualitative Performance Objectives (Continued)

Performance Objective	Metric	Data Requirements	Success Criteria	Results
System Reliability	Time system performs as designed	• Downtime, Uptime • Number of failures • Time to repair • Mean Time Between Failure • Mean Time To Failure • Maintenance and repair logs	8,760 hours (17,520 hours)	Achieved 98%
Qualitative Performance Objectives				
Landscape aesthetics	Appearance: professional opinion of recognized experts in turf science	• Photographic records	Equal or improved appearance of landscape	Slightly diminished appearance but satisfactory
Plant/turf health	Appearance: professional opinion of recognized experts in turf science	• Photographic records	No degradation or improvement of plant/turf health	Slightly diminished but satisfactory
Ease of use	Ability of landscape technician/manager to use/maintain the technology	• Feedback from the landscape technician on maintainability	Equal or reduced workload on landscape technician	Achieved*

(*Some additional workload was caused by pump failure after the demonstration period.)

The results of each performance objective was determined by analyzing the data compiled in Appendix B for both the control plot (i.e., using current/traditional irrigation practices) and the smart plot, using the smart water conservation system. The smart and control plots were selected as comparable areas, having similar initial landscape, plant health, plot size, microclimate, sun/wind exposure (i.e., based on the presence of Building 1100 directly adjacent to the study area), and usage/traffic within the landscape.

3.1 Reduction of Potable Water Consumption

Purpose: The DoD has substantial landscape areas that are irrigated with inefficient, traditional systems that can benefit from technologies that reduce potable water usage. It is estimated that smart water conservation technologies along with a water harvesting system can reduce the amount of potable water used for irrigation by approximately 60 to 70%. The primary objective is to determine if these smart water conservation technologies along with water harvesting system can be retrofitted into existing facilities to reduce potable water use by up to 70% in support of meeting EO 13693.

Metric: During the demonstration project, the volume of water used for irrigation at both the smart and control plots were measured and recorded/downloaded on a monthly basis to determine the reduction in potable water usage between the smart water conservation system and traditional irrigation system, respectively (see calculations below).

Data: A total of 24 months of water usage data were collected during the demonstration project. The cumulative volume of water data were collected for each irrigation event by the controller on the smart water conservation system. These data were downloaded on a monthly basis.

Success criteria: Achieve a reduction in potable water consumption greater than 70%.

Achievement: Success criteria were achieved with a reduction in potable water consumption of 81% (see calculations and assumptions below).

Determination: A total of five flowmeters were installed, four within the smart plot and one within the control plot, as follows:

- Flow meter #1 – Measures the flow rate and total volume of HVAC condensate water contributing to the UST.
- Flow meter #2 – Measures the flow rate and volume of rain water overflow exiting the UST during a rain event.
- Flow meter #3 – Measures the flow rate and total volume of potable water contributing to the UST to supplement irrigation for the smart plot.
- Flow meter #4 – Measures the flow rate and total volume of water actively pumped from the UST to support irrigation of the smart plot.
- Flow meter #5 – Measures the flow rate and total volume of potable water used by the traditional irrigation system to support irrigation of the control plot.

Figure 2 illustrates the relative location of the flow meters (or totalizer) on the control and smart plots used to determine reduction of potable water consumption. The control plot was watered using a timer-based, traditional irrigation system that is currently in place and operated by the facility at the demonstration site. As stated previously, the traditional irrigation system was outfitted with a flow meter (i.e., Flow meter #5) to measure the total volume of potable water used to irrigate the control plot during the two year demonstration period. The total volume of potable water used to irrigate the control plot is represented by Equation 1. Small leak losses through the tank walls at pipe penetrations were minimal and not included in any of the following calculations.

$$\text{ControlVol}_{\text{potable}} = \text{ControlVol}_{\text{irrigated}} + \text{Losses} \quad \text{(Equation 1)}$$

Where:

- $\text{ControlVol}_{\text{potable}}$ = cumulative volume of potable water used to irrigate the control plot during the demonstration period (Flow meter #5)
- $\text{ControlVol}_{\text{potable}} =$ 67,423 gal

The smart plot demonstration area was equipped with four flow meters to measure the total volume of rain water overflow exiting the UST, HVAC condensate water entering the UST, make-up potable water entering the UST, and smart plot irrigation water exiting the UST. Rain water that was collected within the UST was determined by manually measuring UST water

levels prior to and after each rain event, and performing a summation of the values for the demonstration period. Flow meter #2 measured the total volume of rain water that could have been harvested had the UST been larger, and differentiates water collected within the UST from water that flowed through the UST.

Water from the potable water supply system was introduced into the UST as needed to ensure that the pump inlet remained fully submerged in the tank. This potable water (i.e., $SmartVol_{potable}$) was used to irrigate the smart plot, as needed and compared to the potable water used to irrigate the control plot. The volumetric balance of water in the UST and water used to irrigate the smart plot is shown in Equation 2.

$$SmartVol_{potable} + Vol_{rain} + Vol_{condensate} = SmartVol_{irrigated} + Vol_{overflow} + Losses \quad \text{(Equation 2)}$$

Where:

- $SmartVol_{potable}$ = total volume of potable water contributed to the UST (Flow meter #3)
- Vol_{rain} = total volume of rain water contributed to the UST (summation of UST water level increase after rain event)
- $Vol_{condensate}$ = total volume of HVAC condensate water contributed to the UST (Flow meter #1)
- $SmartVol_{irrigated}$ = total volume of water used to irrigate the smart plot (Flow meter #4)
- $Vol_{overflow}$ = total volume of water that has overflowed from the UST (Flow meter #2)

The simplest approach to determine the reduction in potable water consumption is to determine the difference in cumulative volumes of potable water used to irrigate the control plot compared to the smart plot (see Equation 3). The success criterion for this performance objective is 70% reduction. $SmartVol_{potable}$ is the cumulative volume of potable water passing through Flow meter #3. However, Flow meter #3 includes the total volume of potable water used to irrigate both the smart plot turf and groundcover areas served by the UST. Therefore, separate flow data was collected for both the smart plot and groundcover area using Flow meter #4, which were irrigated on separate schedules.

Approximately 51% of the total volume of potable water was applied to the smart plot (see Appendix B). Accordingly, for equal comparison the total volume of potable water applied to the smart plot was multiplied by 0.51 (i.e., equal to 12,843 gal).

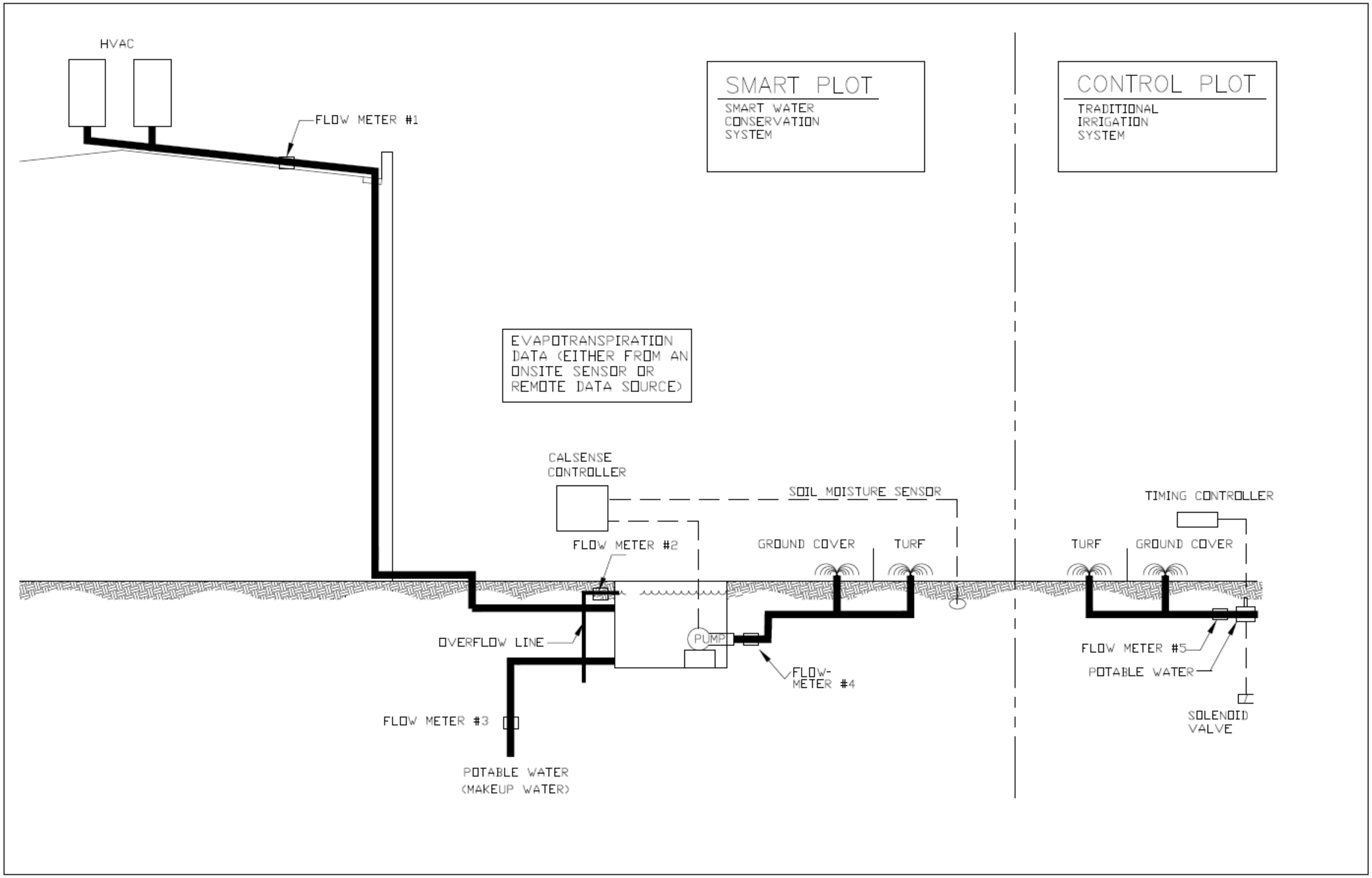

Figure 2. Details of Smart Water Conservation System, Traditional Irrigation System, and Flow Meters Used to Quantitatively Evaluate System Performance

$$\text{Percent Reduction} = (\text{ControlVol}_{\text{potable}} - \text{SmartVol}_{\text{potable}}) / \text{ControlVol}_{\text{potable}} \quad \text{(Equation 3)}$$

$$\text{Percent Reduction} = (67{,}423 \text{ gal} - (25{,}183 \text{ gal} \times 0.51)) / 67{,}423 \text{ gal}$$

$$\text{Reduction of Potable Water Consumption} = 81.0\%$$

Where:

- ControlVol potable = Cumulative volume of potable water used on control plot (Flow meter #5)
- SmartVol potable = Cumulative volume of potable water used on smart plot (Flow meter #3)

3.2 Reduction of Potable Water Costs

Purpose: The primary purpose of the cost reduction performance objective is to determine the annual cost savings resulting from the displacement of potable water use and any resulting decrease in electrical use due to the smart water conservation system. The percent reduction in potable water cost is expected to be approximately equal to the reduction in potable water consumption, since there is only a minimal cost associated with pumping the harvested water and supplemental potable water. In addition, the pumping occurs on-site, pump size and pressure is optimized, and pressure loss is held to a minimum. The reduction in potable water cost can be used to determine the payback on investment for follow-on system implementation.

Metric: Total volume of water used to irrigate the control plot and smart plot, an average water rate/cost, an average electrical cost, and hours of pump operations were used to calculate reduction in potable water cost.

Data: During the demonstration project, potable water use, harvested water use, and flow data were collected (over a 24 month period) and used to determine hours of pump operation. The cumulative volume of water data were collected during each irrigation event by the controller on the smart water conservation system. These data were downloaded on a monthly basis. Water rates and electrical costs were captured from average local utility bills.

Success Criteria: Achieve a reduction in potable water cost greater than 50% to support an economic payback/return on investment.

Achievement: Success criteria were achieved with a reduction in potable water cost of 81% (see calculations and assumptions below).

Determination: The reduction in potable water cost was determined by comparing the cost of potable water used to irrigate the control plot with the cost of potable water used to irrigate the smart plot (see calculations below). The smart plot has two cost factors: 1) the electrical cost to pump water from the UST to the smart plot and 2) the cost of the makeup (i.e., potable) water contributing to the UST.

The electrical or pump cost to irrigate the smart plot was determined assuming an electrical cost of \$0.14 per KWh and a flowrate set at 13 gpm throughout the demonstration period. In addition, a water rate or cost of \$6.54 per 1,000 gallons was used to determine the cost reduction. Since many municipalities provide incentives to consumers to conserve water, this unit cost takes into account the rate that would have been charged if no reductions were made by the consumer. The cost of pumping 12,843 gallons of potable water for irrigating the smart plot was used in the analysis (see Equation 4).

Pump Cost = Cost per Hour × Total Hour

$$\text{Cost per Hour} = 0.746\ Qhc / 3960\ \mu_m\ \mu_p$$
$$\text{Cost per Hour} = 0.746 \times (13\ \text{gpm}) \times (92\ \text{ft}) \times (0.14) / 3960 \times (0.7) \times (0.6)$$
$$\text{Cost per Hour} = \$0.075$$

Where:

Q = Flow rate (gpm)
h = Head (ft)
c = Electrical cost per KWh
μ_m= Motor efficiency
μ_p = Pump efficiency

Total Hours = (12,843 gallons/13 gpm) / 60 min = 16.5 hours

Pump Cost = \$0.075 × 16.5 hours = \$1.24

$$\text{Cost Reduction} = \left[\frac{(\text{ControlVol}_{\text{potable}} \times \text{ unit cost})\text{-}((\text{SmartVol}_{\text{potable}} \times \text{unit cost}) + \textit{pump cost})}{\text{ControlVol}_{\text{potable}} \times \text{ unit cost}}\right] \times 100\%$$

(Equation 4)

$$\text{Cost Reduction} = \left[\frac{(67{,}423\text{ gal} \times \$6.54/1000\text{gal})\text{-}((12{,}843\text{ gal} \times \$6.54/1000\text{gal}) + \$1.24)}{67{,}423\text{ gal} \times \$6.54/1000\text{gal}}\right] \times 100\%$$

Cost Reduction = 81.2%

Where:

- $\text{ControlVol}_{\text{potable}}$ = cumulative volume of potable water used on control plot (Flow meter #5)
- $\text{SmartVol}_{\text{potable}}$ = cumulative volume of potable water contributed to the UST (Flow meter #3)

3.3 Economic Payback Period and Savings to Investment Ratio

Purpose: The primary purpose of the economic payback period and savings to investment ratio (SIR) performance objectives are to demonstrate the economic feasibility of implementing a smart

water conservation system at an existing DoD facility. Specifically, these performance objectives will determine if the system or components of the system are financially feasible for potential widespread implementation at sports field, parade grounds, and/or landscape near buildings. Appendix C details the life cycle cost for the smart water conservation system.

Metric: System capital equipment costs were compared to annual cost saving to calculate an economic payback period and SIR. Costs for the smart water conservation system design, capital equipment, installation, potable water, pumping, and annual maintenance were included in the evaluation.

Data: The data required to complete the analysis include costs for electrical and water; design, capital equipment, and installation of the smart water conservation system; and operational and maintenance.

Success Criteria: Achieve an economic payback period of less than or equal to 20 years and a SIR greater than 1.0.

Achievement: Not achieved. The payback for the smart water conservation system deployed at Naval Base Ventura was 53 years. SIR = 0.53.

Determination: The National Institute of Standards and Technology (NIST) Building Life Cycle Cost Program was initially used to evaluate the smart water conservation system economic payback period and SIR. However, the payback period for the entire system was outside the limits of the program, so a simplified excel spreadsheet was developed to perform the economic analysis.

The spreadsheet incorporated a 4% discount or interest rate for the lifecycle cost calculation (see Appendix C). A 4% interest rate is approximately the long-term government bond rate and represents the cost of alternative uses for capital investment funds. For the purposes of evaluating this performance objective, the economic payback is considered the time period when the discounted future savings of a project (i.e., the smart water conservation system) repays the initial investment costs. The future savings was determined based on a comparison of the annual reduction of potable water used and the associated cost (as compared to the traditional irrigation system) and any reduction in annual operation and maintenance costs associated with the smart water conservation system. Payback was calculated based on a present worth evaluation of the annual cost savings, assuming that interest is compounded continuously. The economic payback period equals the point that the present worth of the annual cost savings is greater than the initial investment costs of the smart water conservation system. If the economic payback period was less than or equal to 20 years, then this performance objective is considered achieved for the demonstration project.

3.4 Overall Energy Use Reduction

Purpose: The purpose of the energy use reduction performance objective is to demonstrate the overall energy saving resulting from using smart water conservation technologies compared to traditional irrigation systems. Potable water used for irrigation purposes at (NBVC is provided by the Port Hueneme Water Agency, whose source water includes local groundwater and water purchased from Calleguas Municipal Water District). The Calleguas Municipal Water District

imports water from the Metropolitan Water District of Southern California (MWDSC), who acquires raw water from Northern California (Sacramento Delta) and the Colorado River. The MWDSC published energy cost for water supplied to users in Southern California is $161 per acre foot and reflects the electrical cost associated with the following:

1. pumping raw water to treatment plants;
2. treatment at the water plant (i.e., pumps, injection systems, mixers);
3. pumping treated water to the end user/customer and maintaining adequate pressure and disinfectant; and
4. the 10 to 20% overburden due to water lost through leaking water distributions systems.

The energy cost to manufacture and transport the treatment chemicals (e.g., chlorine, fluoride, alum, etc.) used in potable water treatment is not included in this evaluation, but is an important consideration to overall energy saving.

On-site harvested water is free of treatment chemicals and has a significantly smaller electrical footprint than potable water. Specifically, a smaller pump operating at lower pressure due to reduced friction losses results in increased energy saving using harvested water. Quality of rainwater should also enhance overall turf health; thereby, reducing the requirement for fertilizers and maintenance. Energy reductions for these benefits are not included in the calculations, but are important factors to note.

Metric: The metrics used to measure energy use reduction were: 1) the published energy cost to supply water to customers in southern California and 2) the energy cost to irrigate with an on-site pump. Regional energy cost for potable water is $161 per acre foot (or $0.49/1,000 gal) and the average cost of electricity is $0.14 KWh.

Data: The data required is the volume of water used to irrigate the control plot and smart plot, cost of electrical power, and hours of pump operation (in addition, see Section 3.2).

Success Criteria: Achieve an energy use reduction of greater than 40%.

Achievement: The smart water conservation system achieved an energy use reduction of 57.4% compared to the traditional irrigation system.

Determination: The energy analysis compared the energy cost to harvest and use water generated on-site for the smart water conservation system with energy costs resulting from imported off-site potable water for the traditional irrigation system.

$\text{Energy Cost}_{\text{Control}} = 67{,}423 \text{ gal} \times \$0.49/1{,}000 \text{ gal}$
$\text{Energy Cost}_{\text{Control}} = \$33.04$
$\text{Energy Cost}_{\text{Smart}} = \text{Pump Cost} + \text{Energy Cost (make-up water)}$
$\text{Pump Cost} = \$0.075 \times 16.5 \text{ hours} = \$1.24$ (see Section 3.2)
$\text{Energy Cost (makeup water)} = 12{,}848 \text{ gal} \times \$0.49/1{,}000 \text{ gal} = \$12.85$
$\text{Energy Cost}_{\text{Smart}} = \$1.24 + \$12.85 = 14.09$

$$\text{Energy Use Reduction} = [(\text{Energy Cost}_{\text{Control}} - \text{Energy Cost}_{\text{Smart}}) / \text{Energy Cost}_{\text{Control}}] \times 100\%$$

$$\text{Energy Use Reduction} = (\$33.04 - \$14.09) / \$33.04 = 57.4\%$$

3.5 Reliability and Availability

Metric: System reliability is defined as the probability that equipment provided will perform its designed function over a specified period of time, or simply the amount of time the system performs as designed. Reliability is quantified as mean time between failures (MTBF) for repairable products such as pumps, and mean time to failure (MTTF) for non-repairable products such as sensors. Table 3 details the reliability and availability of each component of the system.

Repair and replacement for each of these components were kept throughout the 2 year monitoring program to monitor failure and to calculate MTBF and MTTF. The formula for calculating MTBF is:

$$MTBF = T/R$$

Where:

T = Total time
R = Number of failures

The formula for calculating MTTF is;

$$MTTF = T/N$$

Where:

T = Total time
N = Number of units under test.

Availability (A_0) is described as the amount of time a system is operational or ready to operate. Availability is directly related to MTTF and MTBF, and computed using the following formula

$$A_0 = MTBF / (MTBF + MTTR + MLDT)$$

Where:

MLDT = mean logistic delay time (time a technician receives a trouble call to fix and show up with parts and tools)

A simpler approach and that used in this report is to use the following equation for the entire system

$$A_0 = (\text{Up Time}) / (\text{Up Time} + \text{Down Time})$$

The same data used to monitor reliability were used to compute availability for each of the individual components and the system as a whole. System availability is projected to be over 95%. Data sheets were used to capture the date and duration of each repair and the associated system

downtime. The collected information provides a repair record that identifies problematic system components and design practices.

Success Criteria: The reliability and availability success criteria established for the smart water conservation system is greater than 95%

Achievement: Target 95% was achieved.

Table 3. Reliability and Availability of Equipment

Equipment	Number of Failures	Time to Repair	Mean Time Between Failures (hrs)	Mean Time To Failure (hrs)	Availability (%)	Success Criteria	Notes
Submersible Pump	1	14 days*	>17,520 (18,240)*	NA	100 (98)	Met	* Pump failed one month outside of demonstration period. Manufacture recommended replace versus repair. Actual replacement time was 4 hours. Time to replace was mainly awaiting procurement of new pump. Recommend backup kept on site as government procurement process is not expedient. Pump was estimated to last at least 5-7 years. Possible cause of early failure was initial improper float system on/off setting causing pump to run dry.
Makeup Water Subsystem (Float Controls)	0	--	NA	>17, 560	100	Met	Float initially set too low causing pump to surge on and off.
Controller	0	--	>17,560	NA	100	Met	Controller operated as designed for the 24 month period
Soil Moisture Sensor	0	--	NA	>17,560	100	Met	Sensor performed as designed for the 24 month period. Gopher hole in close proximity to the sensor was a problem causing the moisture reading to be non-representative of plot.
Irrigation Spray Heads	0	--	>17,560	NA	100	Met	Reduced maintenance frequency resulted in blockage of sprinkler trajectory. Government sequestration caused budget shortfalls.
Evapotranspiration Communications	--	--	--	--	--	--	ET communication link were disrupted several times during the demonstration due as computer interface was turned off which resulted in monthly historical ET being used in lieu of actual measured ET.

3.6 Ease of Use

Purpose: The purpose of the "Ease of Use" qualitative performance objective is to provide an evaluation with respect to the feasibility of implementing a smart water conservation system for irrigation.

Metric: The performance metric is the ability of landscape technicians or managers to use and/or maintain the smart water conservation system technology.

Data: The project engineers interviewed landscape technicians to obtain their feedback or input on the "ease of use" of the smart water conservation system. The landscape technicians provided feedback on their ability to operate the Calsense 2000E smart irrigation modular controller, and system maintenance based on "workload" and "ease of use". In addition, data was compiled on reliability, maintainability and time required for operation and maintenance.

Success Criteria: The success criteria are equal or reduced workload on landscape technicians or managers due to implementation of the smart water conservation system.

Achievement: Overall, workload was only marginally increased; therefore, the "Ease of Use" qualitative performance objective was achieved.

Determination: With the exception of a few call-ins to the Calsense help-line, the smart water conservation system is generally considered user-friendly and easy to use based on feedback from landscape technicians and managers. Table 4 provides the workload and ease of use ratings for the smart water conservation system components.

Table 4. Ease of Use Qualitative Performance Objective

Smart Water Conservation System Component	Workload Rating	Ease of Use Rating	User Comments
Condensate Collection Subsystem	3	1	Simple piping system. No additional workload.
Rainwater Collection (First flush Devise)	5 * 3 **	4 * 2 **	COTS first flush diverter required maintenance after each storm. New design is user friendly. Automatic self-drain worked.
Harvest Tank	4	2	Requires some additional visual inspections and first year leak evaluation while tank is under 1 year warranty.
Et Controller	Initial workload is a 4, but after setup it is a 1.	3	Requires some time to learn how to adjust soil sensor setting, program for soak and cycle. Controller sensor field technician readily available for product support.
Irrigation Pump	5	1,5	Requires some know-how on pump replacement when pump fails.
Sprinklers	2	2	No new requirements.
Pressure Regulating Devise	2	2	Requires initial pressure settings.
Flow Sensor	4	3	No reported problems except for damaged wire caused by gophers.
Soil Moisture Sensor	4	2	No reported problems except for non-representative plot readings caused by gopher hole near sensor.

*COTS

** Navy Developed First Flush Diverter

Workload Rating: 1-Less Workload; 2-Equal Workload; 3-No Added workload; 4-Slightly More Workload; 5-More Workload; 6-Significanlty More.

Ease of Use Rating: 1 - Very Easy; 2 – Easy; 3- Neutral; 4- Difficult; 5- Need a new skill set.

4.0 FACILITY/ SITE DESCRIPTION

4.1 Facility/ Site Location and Operations

The demonstration of the smart water conservation technology for landscape irrigation was conducted at NBVC, located northwest of Los Angeles, California and includes NCBC Port Hueneme, California. The primary mission of NCBC is:

> *To support the Naval Construction Force, fleet units and assigned organizational units deployed from or home ported at the CBC; to support mobilization requirements of the Naval Construction Force; to store, preserve, and ship advanced base mobilization stocks; to perform engineering and technical services, and such other tasks as may be assigned by higher authority.*

Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) specializes in environmental and energy projects, including water conservation. NAVFAC EXWC's Environmental and Energy and Utilities Departments are standing at the forefront of implementing innovative technology to conserve water resources and reduce energy consumption. These two departments have collaborated to modernize Building 1100 at NCBC Port Hueneme, California (see Figure 3), to achieve a Leadership in Energy and Environmental Design (LEED) "Silver" rating. Implementing and showcasing new, innovative technologies, such as the smart water conservation system, is supported at the command and department levels.

As such, NAVFAC EXWC Building 1100 served as the demonstration site for the smart water conservation system. Building 1100 is a relatively new building (constructed in 1994) and houses over 500 engineers, scientists, and support staff. Figure 4 provides a general layout of the demonstration area immediately north and west of Building 1100, including the location of the smart plot, control plot, approximate rainwater harvesting area, 17,000 gallon UST and Calsense 2000E controller, and two 20-ton rooftop HVAC systems. The rooftop HVAC systems are centrally located on Building 1100 and regulate building temperature and humidity during normal business hours.

The smart plot and control plot were carefully selected based on the comparability of each area. Figure 4 provides a general plan view of the smart plot and control plot at Building 1100. Both the smart and control plot have a turf area (1000 square feet) located at the main entrance of Building 1100 with an accompanying Myoporum ground cover area (6,500 square feet) situated further away from the main entrance. Figure 5 provides a close up of each turf area with the groundcover in the background. Specifically, each area is the same size, contains similar landscaping, and is located on the north side of Building 1100; therefore, sun and wind exposure are similar. Additionally, the control plot was equipped with an existing traditional irrigation system, which served as the baseline against which the smart water conservation system was measured during the project.

Figure 3. NAVFAC EXWC Building 1100 Located at NBVC Port Hueneme, California

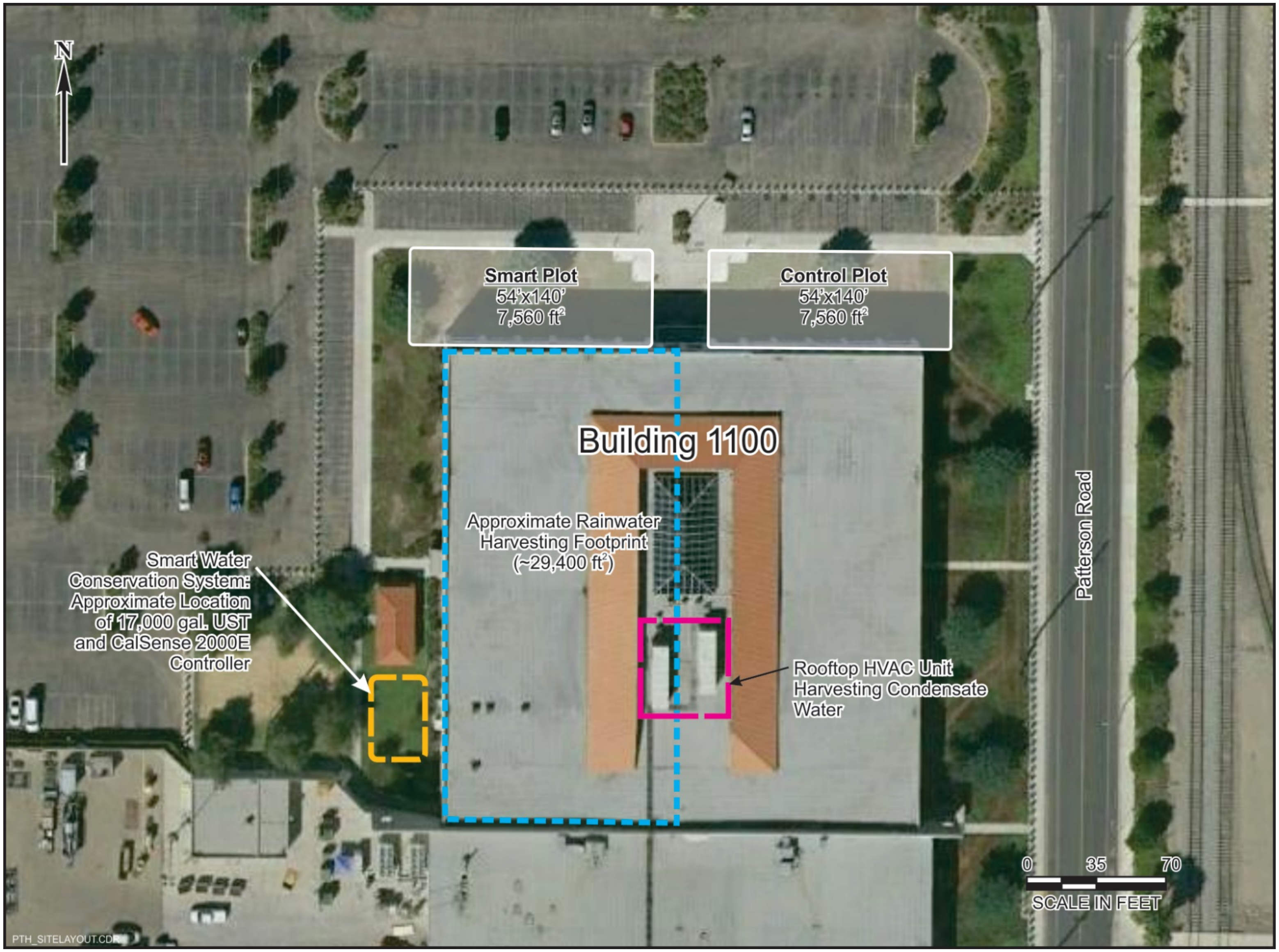

Figure 4. Demonstration Area Immediately North of Building 1100 Depicting the Smart Plot, Control Plot, the Approximate Rainwater Harvesting Area, and the Underground Water Storage Tank

Figure 5. Photographs of Control Plot and Smart Plot at Building 1100

4.2 Facility/Site Conditions

Due to its proximity to the Pacific Ocean, Port Hueneme is described as having a Mediterranean climate and often experiences periods of fog in the early mornings. The average temperature is approximately 60 ºF with an average high and low of 70 ºF and 51 ºF, respectively. On occasion, Port Hueneme experiences hot, high winds blowing from the desert region known as "Santa Anas," which can blow at gusts greater than 40 miles per hour (mph) on the coast. Table 5 summarizes monthly rainfall, ET rates for grass (tall fescue), and humidity in Port Hueneme. These data were used to properly size the water harvesting system.

Table 5. Summary of Monthly Weather Conditions for Port Hueneme, CA

Month	Avg. Rainfall (in.)	Avg. Evapo-Transpiration (in.)	Humidity	
			High (%)	Low (%)
January	3.0	1.83	80	57
February	3.1	2.20	79	58
March	2.4	3.42	83	60
April	0.9	4.49	76	58
May	0.1	5.25	83	60
June	0.0	5.67	88	62
July	0.0	5.86	90	64
August	0.1	5.61	86	63
September	0.4	4.49	81	62
October	0.3	3.42	77	52
November	2.0	2.36	81	55
December	2.0	1.83	83	60
Annual	**14.3 (Total)**	**46.43 (Total)**	**82 (Avg)**	**59 (Avg)**

Potable water supplied to NBVC originates from the Sacramento Delta, Colorado River, and local source waters and is provided by the Port Hueneme Water Agency and Base Public Works. The average cost of potable water is approximately $6.95 per 1,000 gallons; however, costs vary depending on availability and drought conditions. Costs most likely have increased due to the

Continued State of Emergency because of the ongoing drought throughout the state. For purposes of this report the year 2010 billing rate of $6.54 per 1,000 gallons was used on all economic analysis.

4.2.1 Site-Related Permits and Regulations

Guidelines for rainwater harvesting are largely unaddressed by regulation and generally, only a few states (approximately 14) and local jurisdictions have established guidelines for rainwater harvesting systems. The U.S. EPA Low Impact Development Center developed *Managing Wet Weather with Green Infrastructure, Municipal Handbook, Rainwater Harvesting Policies* (U.S. EPA, 2008), provides minimum water quality guidelines and treatment options for stormwater reuse. For example, stormwater for outdoor use, such as irrigation, suggest pre-filtration with a first flush diverter. However, stormwater for indoor use requires a first flush diverter, a 5 micron sediment filter, and chlorination or ultraviolet disinfection.

In addition, water harvesting systems have been used for years without specific design requirements other than standard plumbing regulations for siting of tanks and piping systems. Neither the Uniform Plumbing Code nor the International Plumbing Code specifically addresses rainwater or condensate water harvesting. However, various counties and cities within the U.S., such as Berkeley, California, have developed guidelines that highlight general best management practices (BMPs) for rainwater harvesting. Some of the more prevalent BMPs are summarized below:

- Provide first flush diverter to remove ambient contamination from roof runoff;
- Protect existing potable water distribution systems;
  - Reused pipeline should not be cross connected with potable water
  - Provide backflow prevention on nearby potable water systems
  - Provide air gaps for potable water makeup into harvest tanks
- Use rainwater for irrigation only (purple pipe indicating reuse water) and properly labeled “not for human consumption”;
- Do not connect rainwater overflow discharge to sanitary sewer;
- Provide screens on water storage tank openings to prevent mosquito hatching;
- Provide minimum tank setback requirements from buildings and property lines;
- Overflow cannot be discharged over public right-of-way or adjacent property; and
- Provide adequate tank restraints/designs for local seismic and wind conditions.

Most jurisdictions do not require permits to install a rainwater harvesting system with the exception of Colorado and a few counties. In Colorado, a permit is necessary to install a water harvesting system. Some communities in California, such as Berkeley, require a permit for any system over 100 gallons. No known permits are required for installing water harvesting systems at NBVC or other Federal government or military installations outside of Colorado.

5.0 TEST DESIGN

5.1 Conceptual Test Design

Figure 1 illustrates the conceptual schematic diagram of the demonstration study, detailing both smart water conservation system and traditional irrigation system (i.e., control) as well as the location of flowmeters that will be used to quantitatively evaluate and compare performance of each system.

Figure 6 presents a general process flow diagram for operation or irrigation using the smart water conservation system. The Calsense 2000E controller received soil moisture and ET data to determine the pump operation schedule (i.e., time and duration of operation). The controller communicates daily with a pre-existing nearby Calsense ET gauge located on NBVC. The ET gauge is designed to evaporate water at the same rate as tall fescue (representative of existing turf) via a ceramic evaporation plate. ET data is then automatically sent to the controller, which calculates run time for the next irrigation cycle. The ET gauge is inspected and filled with distilled water every 2 months to ensure proper operation.

An irrigation set point or soil moisture content level was established within the controller such that:

- *If* the soil moisture content level (i.e., based on measurements from the soil moisture sensor) exceeded the irrigation moisture set point, *then* the smart water conservation system did not irrigate because the data indicated the soil was sufficiently moist to support plant health within the smart plot.
- *If* the soil moisture content level (i.e., based on measurements from the soil moisture sensor) was below the irrigation moisture set point, *then* ET data were used by the controller to determine whether irrigation was necessary within the smart plot.

This smart water conservation system ensured irrigation only occurred when it was needed, based on site- and area-specific data (i.e., moisture content and ET data). Harvested water (along with potable water, if necessary) within the UST served as the water source and a pump was used to transport this water from the UST to the smart plot during periods of irrigation (i.e., as determined by the controller).

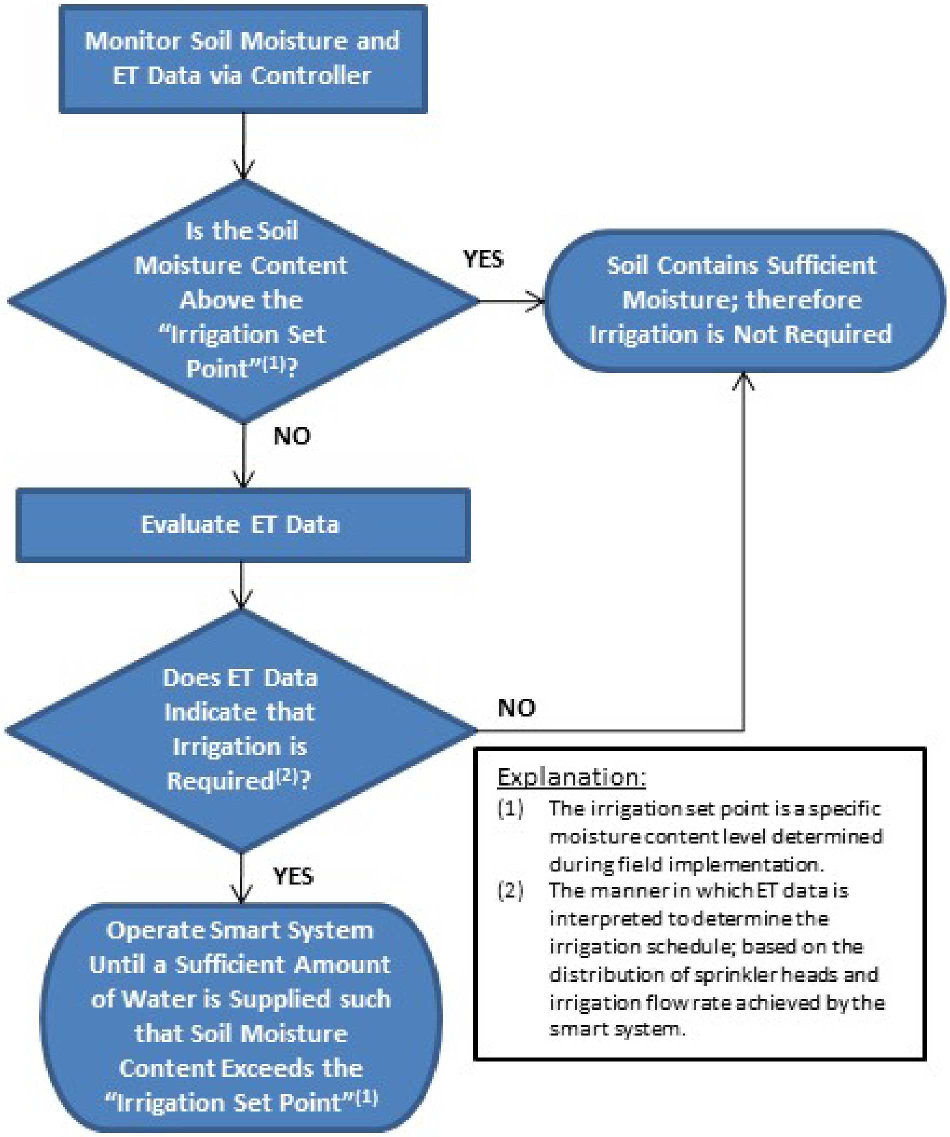

Figure 6. Process Flow Diagram for Operation of the Smart Water Conservation System

5.2 Baseline Characterization

A separate area at the demonstration site served as the control plot and was irrigated using the existing traditional irrigation system. As shown in Figure 4, the control plot was directly adjacent to the smart plot; therefore, it was expected to be highly comparable with micro-climates, soil conditions, and exposure to sun, shade, and wind as the smart plot. Also, there were similarities in the landscape features, such as types of turf, plants, and vegetation density, between the smart plot and control plot.

The control plot was approximately 7,560 ft^2 and covered by two irrigations stations: one for the turf area and the other for ground cover. The turf area was approximately 1,034 ft^2. The station for the ground cover could not be outfitted with a flow meter without major demolition and

construction; therefore, only the turf area was monitored with a flow meter during the demonstration project. As illustrated in Figure 1, irrigation at the control plot was regulated by a simple timer. In order to capture flow data for the demonstration a second Calsense controller was added and configured to operate as a simple timer. Figure 7 presents the general process flow diagram for operation of the timer-based, traditional irrigation system.

Irrigation using a timer-based system is solely dependent on: 1) the time of the year (i.e., summer month verses. non-summer month); 2) the day of the week; and 3) the time of day:

- During the summer months, the timer was set to irrigate the turf and landscape on Monday, Wednesday, Friday, and Saturday between the hours of 10:00 p.m. and 6:00 a.m., which was consistent with current irrigation schedules.
- During the fall/winter/spring months, the timer was set to irrigate the turf and landscape on Mondays and Thursdays between the hours of 10:00 p.m. and 6:00 a.m. This schedule was based on discussions with the irrigation manager from the NBVC Public Works Office.

The 2-year demonstration study began following installation and an initial evaluation of both the smart water conservation system and traditional irrigation system. The overall performance of the traditional irrigation system was assessed using a flow meter capable of monitoring flowrate and total water volume. These performance metrics were monitored on a monthly basis using this flow meter. Appendix B provides a detailed spreadsheet of the total water volume measurements on a monthly basis. To note, some adjustments were made by the landscape technician to the timer on the traditional irrigation system throughout the demonstration period to adjust for drought conditions and maintenance crew activities. Groundskeepers turned off irrigation during the winter months and a few days prior to mowing.

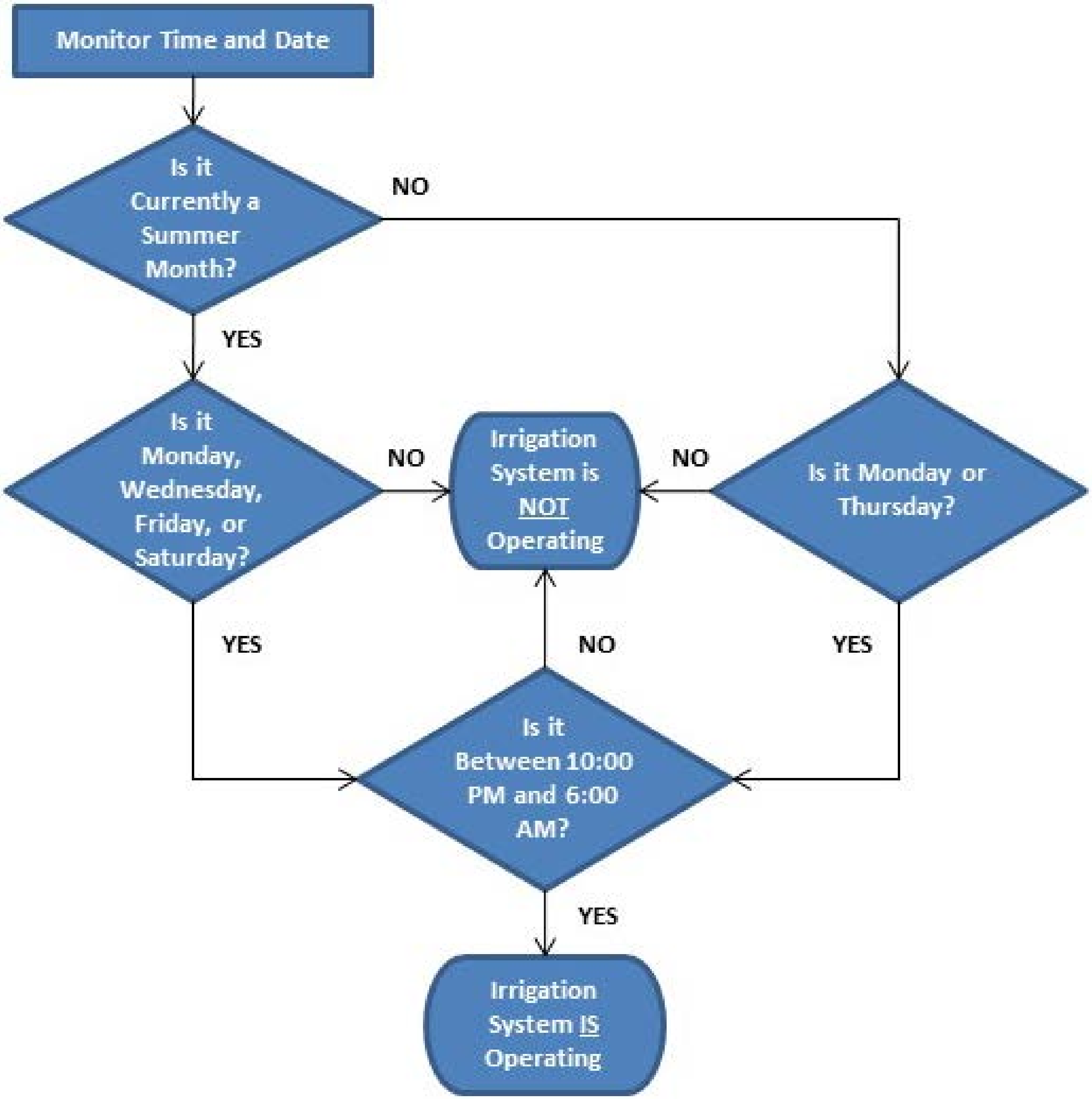

Figure 7. Process Flow Diagram for Operation of the Traditional Irrigation System

5.3 Design and Layout of Technology Components

This section provides a detailed, technical description of the primary components of the smart water conservation system, including the advanced ET controller, rainwater and HVAC condensate water harvesting system, and irrigation hardware. The conceptual design and layout of the smart water conservation system (including components) is illustrated in Figure 1 and the spatial layout of the demonstration site is illustrated in Figure 4.

5.3.1 Advanced ET Controller

The Calsense 2000E smart irrigation modular controller is a programmable logic controller (PLC) and the main interface for the smart water conservation system. Through the use of this controller,

operators are able to program the system to operate/irrigate based on site- and area-specific conditions. Overall, the basic functionality of the Calsense 2000E smart irrigation modular controller includes:

- Ability to control eight irrigation systems (with the option to upgrade up to 32 irrigation systems);
- Flexible programming options and self-diagnostic feedback to identify field wiring, sensor input, and solenoid/valve issues during operation;
- Four separate programmable settings to input different start times, system timing duration, and watering days;
- Ability to draw from non-potable (e.g., harvested) water sources and control pumps and actuated valves, as necessary, to control operation;
- Remote features, such as manual operation, program adjustment, and dial and switch settings via personal computer, radio signal, or cellular network provides substantial travel cost savings by allowing routine irrigation programming modification and, in some cases, more complicated troubleshooting to be conducted remotely (Unfortunately Navy IT requirements only allowed manual input/output via hard wire connection at the Port Hueneme demonstration site) ;
- The controller utilizes the following sensors to irrigate the smart plot: 1) a pre-existing nearby Calsense ET gauge to calculate the irrigation run time correlating to existing weather conditions; 2) a soil moisture sensor to terminate irrigation if actual soil moisture meets the programmed set-point; and 3) a rain gauge that terminates irrigation upon a rain event, offsets ET losses, and adjusts run time for following irrigation cycles. Figure 8 provides a photograph of the Calsense 2000E controller as well as ET sensor and rain gauge used during the demonstration project.
- One of the primary objectives of this project was to demonstrate the controller's ability to effectively and efficiently manage landscape irrigation by using real-time soil moisture, ET, and rainfall data as well as multiple water harvesting sources to minimize the volume of potable water required for landscape irrigation. Overall, the Calsense 2000E controller and system components were selected, installed, and demonstrated to determine the feasibility of irrigating, as needed, based on site- and area- specific conditions. Appendix A provides the manufacturer's specification sheet for the Calsense 2000E smart irrigation modular controller.

Figure 8. Calsense 2000E Smart Irrigation Modular Controller, ET Gauge, and Rain Gauge *(Clockwise from Left)*

5.3.2 Rainwater and HVAC Condensate Water Harvesting System

The smart water conservation system includes a water harvesting system, capturing both rainwater and HVAC condensate water to displace potable water usage for irrigation. The water harvesting system captures roof rainwater from the western half of Building 1100, which gravity feeds through three downspouts to a 17,000 gallon UST located approximately 25 feet west of the building foundation. At the base of the building, rooftop runoff flows through first flush diverters to redirect the first portion of a storm event to the storm sewer. The first flush of rooftop runoff typically contains debris such as bird droppings and sand size particles that can accumulate in the UST, or clog the sprinkler irrigation hardware.

Figure 9 shows the two types of first flush diverters installed at the base of Building 1100. The left side of the photograph shows a flow rate based first flush diverter valve, and the right side of the photograph shows a constant volume 100 gallon first flush diverter. The diverter valve design was installed on two of the three downspouts leading to the UST, while the remaining downspout was served by the constant volume first flush diverter. In either scenario, conventional design guidance suggests diverting 1 liter per square meter roofing for lightly loaded roofs and 2 liters per square meter for heavier loads.

Constant volume first-flush diverters fill to capacity when a rain event begins regardless of the rain intensity. Once full, rainwater is then conveyed to the UST. If they are sized correctly, the

rainwater sent to the UST will be essentially free of contaminates and debris. The first flush runoff volume slowly drains from the diverter over the next 72 hours via a weep hole connected to the storm sewer.

First flush diverter valves are sensitive to the flowrate of the rainwater moving through a downspout or other conveyance. When the flow rate through the device reaches a design minimum, a spring-suspended hollow internal container (i.e. valve ball) located within the diverter body begins to slowly fill with water. As the valve ball fills, the increased weight of the ball causes it to contact a valve seat and stop diverting water flow. The remaining runoff is then conveyed to the UST.

Both first flush diverter designs have advantages and disadvantages when considering the intensity and duration of each storm event. Conventional wisdom indicates that rain intensity is the critical wash off factor for most storm events. A constant volume first flush diverter may bypass contaminants and prematurely fill to capacity with relatively clean rain water for a storm event beginning with low rain intensity that then builds to a peak. First flush valves operate by flow rate and should not actuate during low intensity rain (drizzle). The design essentially waits until the rain is intense enough to wash the roof, and then diverts the remaining flow to the UST.

Condensate water from the two rooftop HVAC units normally gravity feeds directly to the UST under typical operating conditions. However, to capture flow data for the demonstration the condensate water from the rooftop HVAC system at Building 1100 was rerouted through an overflow downspout via PVC pipe and hose to a temporary holding tank on the western half of the building, where it was directly pumped through a flowmeter and into the UST. All harvested water stored in the UST is pumped to irrigate the smart plot, which utilizes the smart water conservation system.

Figure 9. Diverter Valve and Constant Volume First Flush Diverters Installed at Base of Building 1100

A nominal 17,000 gallon UST (16,755 gallons) was constructed onsite to store the harvested water. For a large facility such as NAVFAC EXWC, an HVAC system can potentially generate 0.4 to 5.3 gallons per hour (gph) of condensate water, depending on the cooling load placed on the chillers (approximately 25,000 gallons annually). In addition, the annual precipitation at Port Hueneme is 14.3 inches (see Table 5). Based on the 29,400 ft^2 rainwater harvest area depicted in Figure 4, an estimated 262,080 gallons of rainwater was anticipated to be produced on an annual basis. The anticipated volume of harvested water (i.e., HVAC condensate water and rainwater) was 287,046 gallons annually, approximately 17 times the volume of the installed UST. There are several methods used for sizing a harvest tank for residential use but if applied to a substantive turf area would require an exorbitantly large size tank. Monthly rainfall and ET rates for tall fescue grass in Port Hueneme, CA were considered in sizing the water harvesting system. Tank sizing is discussed in greater detail in Section 7.2 and Appendix D.

The UST was constructed with 2 ft × 2 ft × 2 ft modular polyethylene cells assembled together with an overall dimension of 14 ft × 40 ft × 4 ft (or 2,240 cubic ft). The nested cells were enclosed with a 36 mil polypropylene liner to hold water. Two manholes were installed on the top of the tank to allow installation of a submersible pump, float switches, and ancillary piping. Holes were installed through the polypropylene liner on the eastern sidewall to accommodate ports for the inlet harvested water and outlet pressure irrigation piping and electrical conduit. In addition, overflow from large rain events was channeled from an overflow pipe installed at the top of the UST and discharged to the storm sewer, as appropriate. The UST was covered with a 2 foot cap of native soil and sand which allows for incidental H-20 traffic loading, equating to a dual wheel live load (i.e., emergency vehicle) of 16,000 pounds without adverse impact to the UST. Figure 10 presents photographs of the construction and installation of the 17,000 gal UST.

Figure 10. Construction and Installation of 17,000 gal UST for Storage of Harvested Water

A 1-horsepower, 110 volt submersible pump was installed at the bottom of the UST to irrigate the smart plot with harvested water. The pump provides approximately 13 gpm at 40 pounds per square inch (psi). A particulate filter or floating screen inlet was also installed to prevent debris from entering the underground sprinkler system that may have inadvertently entered into the UST. The pump was protected from running dry with the use of two low level float switches:

- First float switch – connected to a potable water make-up system that ensures a minimum water level to prevent the pump from running dry (further discussed in following section). A few inches of water is required above the pump inlet to ensure proper operations.
- Second float switch – located a few inches below the first float switch to deactivate the pump if the water level is too low in the event that the potable water supply to the building is turned off.

The pump runtime was regulated by the Calsense 2000E controller.

If rainwater collected from the rooftop and condensate water from the HVAC system were of insufficient volume to keep the pump primed or irrigate the smart plot, then potable water was obtained via the make-up water addition system. This system consisted of piping and a flow control valve/flowmeter connected to the potable water supply (i.e., after a backflow preventer). When

activated by the second float switch and directed by the Calsense 2000E controller (i.e., prior to irrigation), the flow control valve opened allowing potable water to flow into the 17,000 gal UST to supplement the harvested water. The makeup water level within the UST was set at a minimum to allow the greatest available volume for rain harvest.

5.3.3 Water Efficient Sprinkler Heads, Flow Meters and Pressure Regulating Device

Efficient irrigation hardware, including pipeline design, multiple high-efficiency volume sprinkler nozzles, pressure regulating valves, and flow meter, were also part of the smart water conservation system. For the demonstration project, Rain Bird® MPR 10 Series sprinkler nozzles were used and integrated with a pressure regulating valve set at 30 psi. These sprinkler nozzles are designed to provide even water distribution with a 10 ft radius, when properly installed and pressurized. The regulating valve device minimizes water loss caused by excessive/over pressure to the sprinkler nozzle, which causes misting resulting in overspray. Appendix A provides the specification sheet for the Rain Bird® MPR 10 Series sprinkler nozzles.

A flow meter was installed in the irrigation pipeline as a subsystem of the Calsense 2000E controller. The controller was programmed to alert facility operators when flowrate was above a specified value. High flowrates occur as a result of a breach in the pipeline or broken sprinkler nozzle. Since irrigation occurs in the early morning, typically many days can pass before the operator is alerted to the signs that there is a breach in the irrigation system. If sprinkler nozzles are accidently broken by lawn equipment or maintenance crews, then the flowrates exceed normal flow patterns. The controller can detect these changes in flowrate and shut down the irrigation system or provide an e-mail alert to operators. Figure 11 provides photographs of a high-efficiency volume sprinkler nozzle and flow meter installed as part of the smart water conservation system.

Figure 11. High-Efficiency Volume Sprinkler Nozzle and Flow Meter

5.4 Operational Testing

The primary metric used to measure the performance of the smart water conservation system was the reduction in potable water consumption used for irrigation compared to the timer-based, traditional irrigation system. Flow rates and cumulative water volumes were the primary data collected to evaluate the performance of the system. These performance data were collected from the demonstration site on a monthly basis for two years, which was scheduled in three phases (i.e., startup, performance monitoring, and demonstration completion).

5.4.1 Phase I – Startup

Once the smart water conservation system was completely installed on November 01, 2013, a 1 to 2 day system startup and shakedown period was conducted to fully validate and determine the optimal program settings for the controller, based on soil moisture and ET data.

In addition, the performance of the irrigation hardware (i.e., sprinkler nozzles and pressure regulating valve) and metering system (i.e., flow meters that measured performance of the system) were monitored and evaluated during startup/shakedown.

- ***Irrigation Hardware* –** A standard irrigation audit of the sprinklers systems was conducted by the Center for Irrigation Technology (CIT), California State University, Fresno to ensure the system was properly constructed and operating within the irrigated area (i.e., smart and control plot). This was accomplished by placing cups throughout the smart plot and the cups collected water distributed by the sprinkler nozzles for a 10 minute period. The volume of water collected in all of the cups is found in Appendix E. The result ensured similar and equal water distribution was achieved within all areas of the smart plot and control plot. In addition, representative sprinkler nozzles from the smart and control plots were pressure tested to establish a baseline and insure the water pressure as within the manufacturer's specified range for optimal spray coverage and efficiency. Pressure tests were also performed at the conclusion of the 2 year demonstration to determine whether any loss of pressure may have reduced coverage by the irrigation system.
- ***Metering System* –** All flow meters were calibrated to ensure that the data was accurate. This was accomplished by monitoring the volume of water produced by the irrigation system over a pre-determined period of time and comparing this value to the flow meter measurements.

5.4.2 Phase 2 – Performance Monitoring

Performance data (i.e., flowrates and volumes of water from Flow meters #1 through #4) was collected from January 01, 2013 through December 30, 2014 during the demonstration project. The data was logged manually and digitally through an on-demand output obtained from the PLC/controller. Field test data sheets were utilized to assist in collecting data and also to capture qualitative observations made by irrigation system operators, such as the occurrence of standing water, odor, algae formation in the UST, clogging of sprinkler heads, and overall aesthetic condition of the landscape.

Photographs of each plot (i.e., smart plot and control plot) were taken at the first, sixth, and twelfth month and 24 month of the performance monitoring to qualitatively assess the health of the vegetation within each plot. The evaluation included documentation of any degradation in aesthetics or stress, and/or disease resulting from each respective irrigation practice. This qualitative objective was measured by turf scientists on a scale from 1 to 9 (i.e., where 9 is the highest level) using their professional judgment. The photographs and respective expert evaluation were used to determine and document the aesthetics or condition of each plot.

5.4.3 Phase 3 – Demonstration Completion

The final evaluation of the smart water conservation system was performed at the conclusion of the demonstration project and involved interpretation of both the quantitative and qualitative performance objectives (see Table 2). Critical data collected during the demonstration project included the facility's metered water consumption, the water rates for the facility, and flowrates stemming from the water harvesting system and cumulative volume of potable water applied to the control plot.

Final readings on each of the flow meters were logged at the completion of the demonstration period to support generation of the final data set (i.e., volumes of water from all flow meters) and calculation of the overall reduction in potable water use between the smart plot and control plot. A final irrigation audit was conducted and compared to the baseline audit to determine if there were any losses in sprinkler coverage, pressure, and spray pattern during the operational period of the smart water conservation system. Final photographs of the smart plot and control plot were provided to the turf scientists at California State University, Fresno for a qualitative evaluation. Feedback from the NBVC landscape technicians was also obtained to understand the maintainability of the system and whether any significant complications were encountered during the demonstration period. The total runtime for the irrigation pump was also collected from the controller to determine energy used and the associated cost. Metrics, such as silting, clogging, pump failures, and water quality of the water harvesting system, were summarized through lessons learned.

All of the system equipment (with the exception of the personal computer) was permanently installed at the demonstration site, and ownership of the equipment was transferred to the demonstration site facility manager. The personal computer used to remotely and locally run the Calsense software was retained by NAVFAC EXWC and continues to be utilized for non-Navy Marine Corps Intranet (NMCI) proprietary software applications.

5.5 Data Collection Protocol

Flow and electrical use data were measured from the control plot and smart plot to validate the quantitative performance objectives (see Table 2). Table 6 provides the monitoring parameters for the demonstration project. At the onset of the demonstration, the flow meters were evaluated on a daily basis for a one week period to ensure accuracy of flow measurements. In addition, flow data was obtained by a facility technician or project engineer at the end of each month for the duration of the 2-year demonstration project.

The controller collected all water-related data on a daily basis, and stored the data on an internal flash memory for a 31-day period. A laptop computer with Calsense Command Center Software was used to manually collect the data via cable connection on a weekly basis. The collected data was backed up to an NMCI accepted external hard drive using the command center software backup feature. A hardcopy was generated each month and a backup file was stored on the Naval Facilities e-project portal that allows multiple team members and stakeholders to view data and reports.

Flow meters were operated by manually operating the irrigation system once a month for a set time to visually validate accuracy of flowrate and ensure proper operation. Expected flowrates were compared with baseline flows to ensure reasonableness of the data and identify any discrepancies. Flow data accuracy within 5% is considered reasonable.

Accuracy of electrical use data was also validated by comparing metered data to calculated current draws.

The qualitative data was provided by a turf expert highly familiar with plant and turf biology to evaluate any degradation in aesthetics or stress and/or disease to the vegetation. Photographic records were taken for both the smart plot and control plot and used for making visual assessments of the quality/condition of the landscape.

5.5.1 Equipment Calibration and Data Quality

All instrumentation and sensors were calibrated as specified by the manufacturer. Instruments underwent initial calibration and were reevaluated periodically to ensure proper calibration. If there were discrepancies in the data, instruments were inspected and recalibrated, as necessary.

5.5.2 Quality Assurance

Quality assurance of the test protocol was accomplished with monthly inspections of flow meter readings to ensure that the flow meters were functioning properly and within the quantitation limits specified in Table 6.

Table 6. Demonstration Project Monitoring Parameters

Parameter	Method	Medium, Sampling Frequency	Accuracy
Water Volume *	Calibrated flow meters (Flow meter #2 – Flow meter #1)	Volume of rainwater, monthly	± 5%
Water Volume	Calibrated flow meter (Flow meter #1)	Volume of HVAC condensate water, monthly	± 5%
Water Volume	Calibrated flow meter (Flow meter #3)	Volume of potable water entering UST, monthly	± 2%

Water Volume	Calibrated flow meter (Flow meter #4)	Volume of harvested and potable water used to irrigate smart plot, monthly	± 2%
Water Volume	Calibrated flow meter (Flow meter #5)	Volume of potable water used to irrigate control plot, monthly	± 2%

*Tank water level measures were also taken to validate accuracy of flow meters and to validate mass balance of the water harvest tank.

6.0 PERFORMANCE ASSESSMENT

Table 7 summarizes the planned assessment criteria for the performance objectives identified in Section 3.0 and actual performance. The specific assessment methodology of each performance objective is discussed in the following subsections.

Table 7. Expected Performance and Performance Confirmation Methods

Performance Objective	Expected Performance	Performance Confirmation	Assessment	Actual Performance
Quantitative Performance Objectives				
Reduction of potable water consumption	> 70% reduction	Complete and accurate record keeping	Comparison with control plot	The smart water system reduced potable water usage by 81% when compared to the control plot.
Reduction of potable water costs	> 50% reduction	Complete and accurate record keeping	Comparison with control plot	The smart water system reduced potable water cost by 81% when compared to the control plot.
NIST economic payback period and SIR	≤ 20 years, SIR > 1.0	Complete and accurate record keeping	Present worth cost evaluation	The payback period for the system was 53 years.
Overall energy use reduction	> 40% reduction	Complete and accurate record keeping	Comparison of energy cost with the control plot	The system achieved a 96% reduction in energy use as compared to the control plot.
Qualitative Performance Objectives				
Landscape aesthetics	Equal or improved appearance of landscape	Evaluation from turf experts	Comparison with control plot	Slightly diminished appearance but satisfactory
Plant/turf health	No degradation of plant health	Evaluation from turf experts	Comparison with control plot	Slightly diminished but satisfactory
Ease of use	Equal or reduced workload on landscape technician	Experience from demonstration	Comparison with control plot	Additional workload was caused by pump failure. Operators were called in to troubleshoot and perform pump replacement.

6.1 Reduction of Potable Water Consumption

The reduction in potable water consumption is the primary measure of success for the smart water conservation system. The data required for assessing potable water reduction and the method in which this calculation was made is discussed in detailed in Section 3.1, and is the percent difference of the metered cumulative flow (volume over time) of the smart plot compared to the

control plot. These data were captured using industrial-grade flowmeters with an accuracy of ±2%. To ensure the validity of the data, all flow metering devices were calibrated at the onset and data reviewed during the demonstration phase. This final report includes graphical analyses (i.e., graphs and charts) to convey the performance differences between the smart water conservation system and traditional irrigation system; the contribution of rainwater and HVAC condensate water; and the individual technologies.

Assessment Criteria:

- *If* the reduction in potable water consumption between the smart water conservation system and traditional irrigation system achieved 70%, *then* the smart water conservation system was considered to have achieved this performance objective.
- *If* the reduction in potable water consumption between the smart water conservation system and traditional irrigation system was less than or equal to 70%, *then* the smart water conservation system did not achieve this performance objective.

Results: The smart plot reduced potable water usage by 81% when compared to the control plot.

6.1.1 Data Analysis, Interpretation and Evaluation:

Monthly irrigation flow data for the control plot and smart plot were collected for a 25-month period from December 2013 to January 2015. The Calsense ET controller was configured to capture irrigation runtime and log cumulative volume of water passing through the paddle wheel flow meter each day. EXWC personnel downloaded the data to a personal computer at the end of each month. Table 8 displays the cumulative monthly volume of water passing through the flow meter to the control plot and smart plot. Overall, approximately 53,805 gal of potable water were saved over the 25-month period, equating to an 81% reduction.

Table 8. Monthly Water Use for Smart and Control Plot

Month/Year	Total Water Smart Plot (gal) *	Potable Water Smart Plot (gal)	Potable Water Control Plot (gal)
2013			
January	0	0	296
February	0	0	1,461
March	0	0	2,153
April	855	0	1,846
May	883	0	2,302
June	1,020	0	2,902
July	1,013	0	3,118
August	1,716	1,264	3,549
September	2,192	1,811	3,329
October	1,884	2,072	3,496
November	455	763	3,160
December	0	0	3,321
2014			
January	0	0	3,137
February	140	0	650
March	534	0	77
April	1,459	0	1,377
May	2,873	0	4,477
June	2,843	2,087	4,742
July	3,846	1,546	4,970
August	3,296	1,683	4,975
September	2,730	328	4,767
October	1,836	1,293	3,237
November	533	0	2,345
December	0	0	942
2015			
January **	0	0	24
February **	0	0	0
Total	**30,108**	**12,848**	**66,653**

*Total water includes condensate, rainwater and potable water.
**Data downloaded but not used in calculations.

Figure 12 provides a comparison of the total water (including rainwater, HVAC condensate, and potable make-up water) applied to each plot and illustrates the value of the ET/soil sensor component of the smart water conservation system to meet the overall water reduction performance objective. Overall, approximately 36,521 gal of total water were saved over the 2 year period, equating to 54.8 % reduction efficiency and demonstrating the value of the ET/soil sensor.

Figure 13 illustrates the contribution of the ET/soil sensor controller for overall water reduction during the 2-year demonstration. Data were derived by accounting for the days that the soil sensor overrode the computed ET irrigation runtime (i.e., if the soil in the smart plot had adequate moisture to sustain satisfactory turf health, then no additional water was applied).

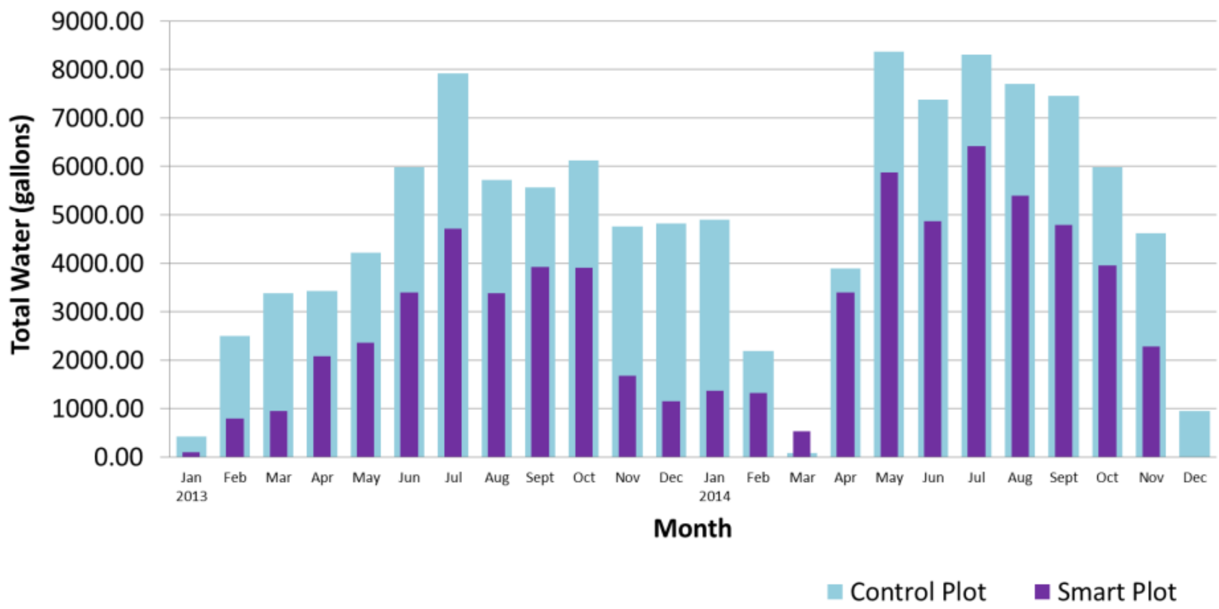

Figure 12. Water Savings by ET and Moisture Sensor

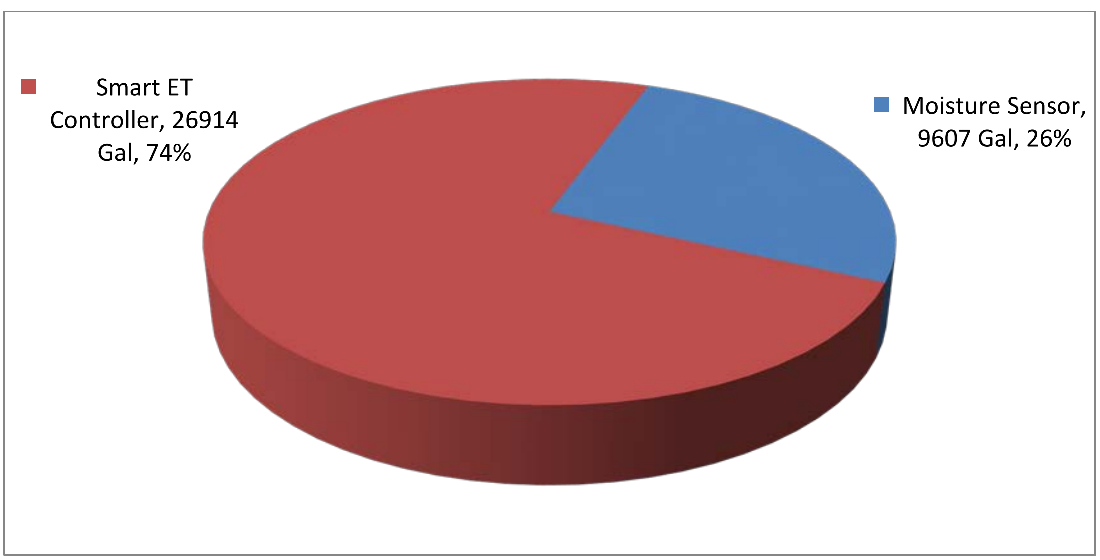

Figure 13. ET Controller and Soil Moisture Sensor Contribution

Figure 14 provides the potable water applied to both the control plot and smart plot and illustrates the potable water displaced by the smart water conservation system. Approximately 53,805 gal of potable water were saved at the smart plot over the 24-month demonstration period when compared to the control plot, equating to an 81% reduction in potable water usage.

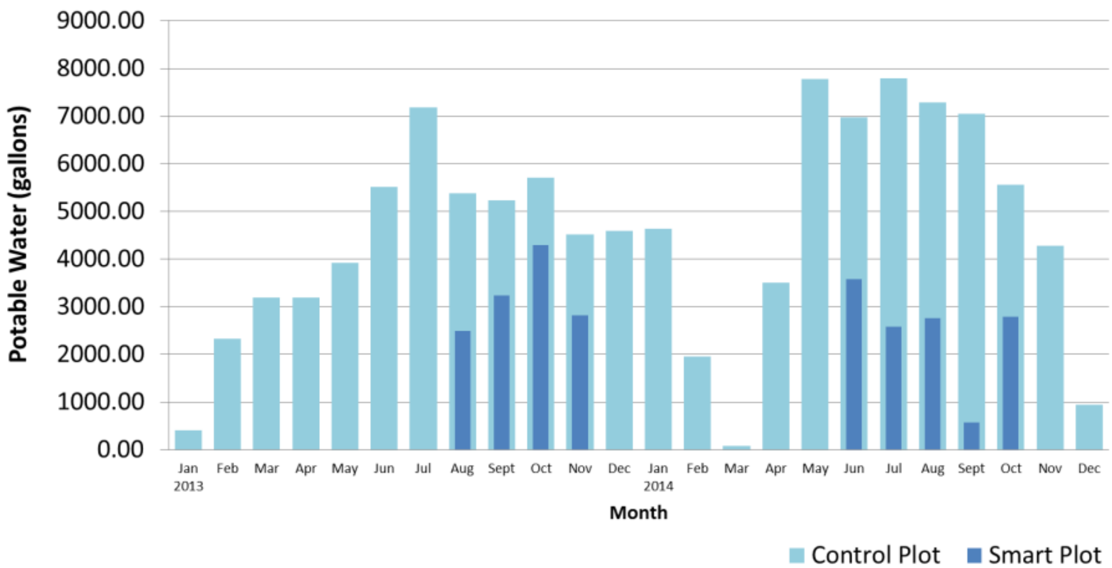

Figure 14. Potable Water Savings by ET and Moisture Sensor

The demonstration project occurred while California was experiencing significant drought conditions, receiving less than 8 inches of rain per year on average. Figure 15 illustrates the volume of rainwater captured during the 2-year demonstration period. As illustrated, there were only 5 months when the volume of rainwater exceeded 2,000 gal (i.e., December 2012 and February, October, November, and December 2014). Figure 16 displays the potential amount of rainwater and actual amount of rainwater captured during the 2-year demonstration period. Figure 16 illustrates that a significant amount of rainwater could have been captured and reused if a larger tank was available. It also illustrates a typical rainy season occurring from November through March in southern California.

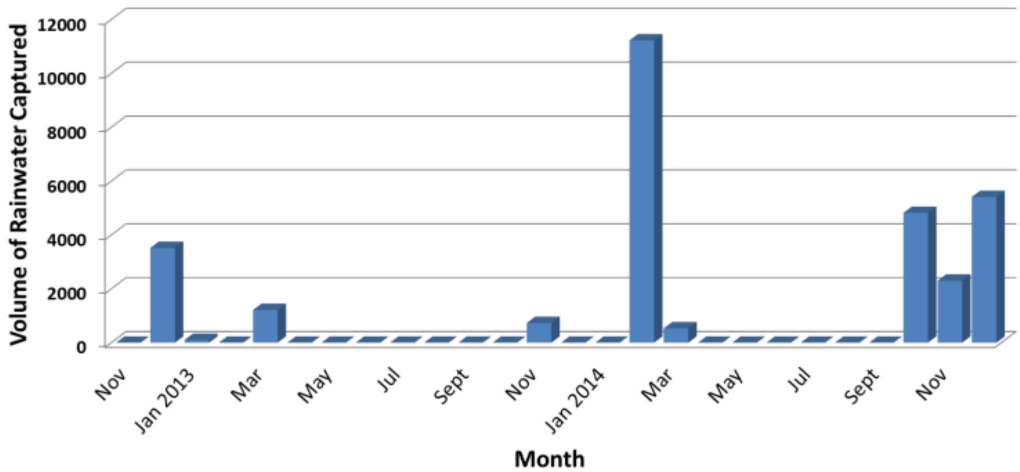

Figure 15. Volume of Rainwater Captured during Demonstration

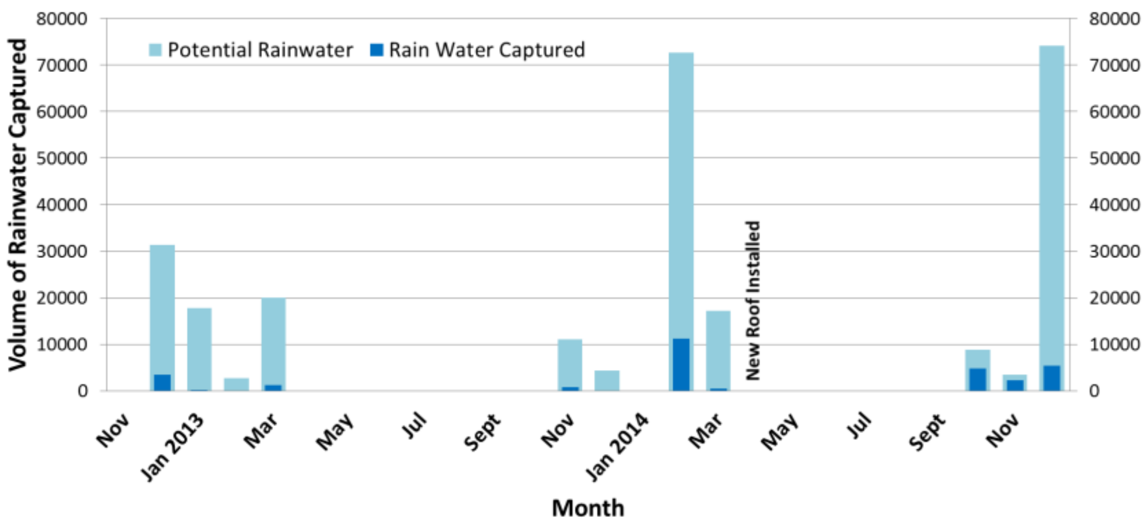

Figure 16. Actual Rainwater Captured Compared to Potential Rainwater from Roof at Port Hueneme

Figure 17 illustrates the HVAC condensate water captured during the 2-year demonstration period and demonstrates that the HVAC system can produce up to approximately 4,000 gallons per month. Only one of the two air handlers was operational in year one and one of the air handlers was under repair during the month of August in year two. The condensate water production from the HVAC unit is at its highest rate during the peak water demand months and generally demonstrates the same peaks as the maximum ET demand of turf (Figure 18); thus, the condensate water is available during the times when the turf is at its maximum demand.

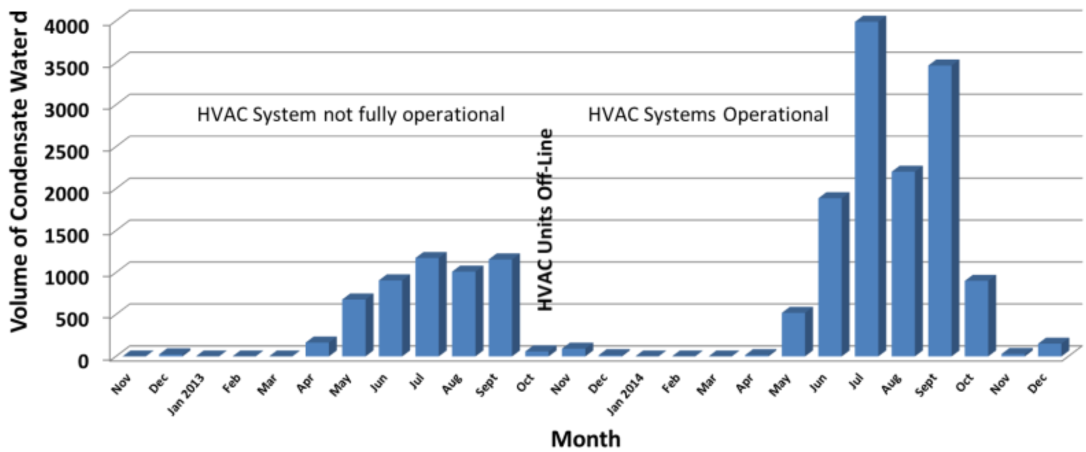

Figure 17. Volume of HVAC Condensate Water Captured during Demonstration

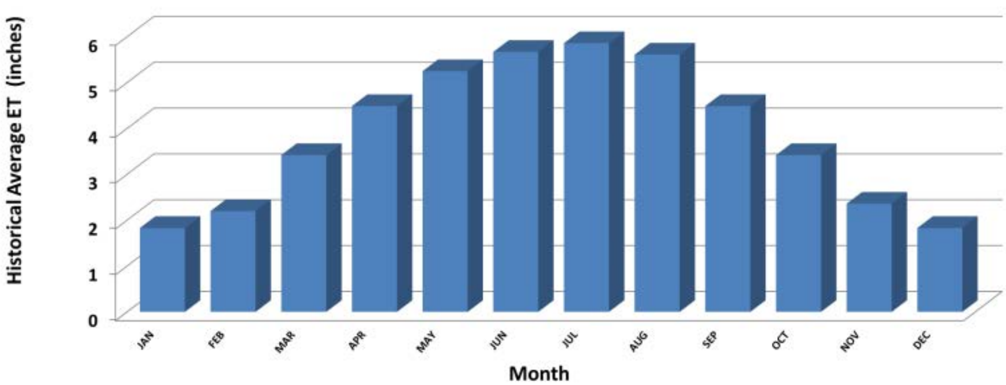

Figure 18. Average Monthly ET Requirement for Turf in Port Hueneme

Figure 19 illustrates the type or source of water used on the smart plot during the demonstration period. The source of water used on the smart plot was relatively equally distributed among rainwater, HVAC condensate water, and potable make-up water at 40%, 24%, and 33%, respectively, with only 3% losses.

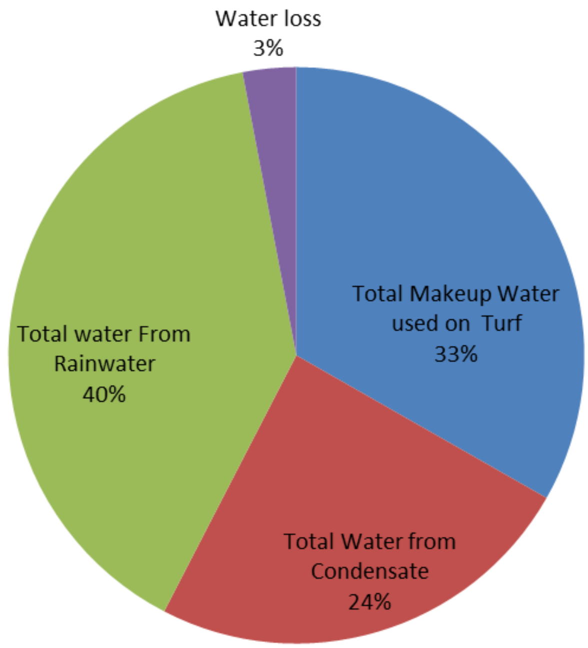

Figure 19. Water Sources Used on Smart Plot

6.2 Reduction of Potable Water Costs

Potable water consumption data obtained from the controller and flowmeters along with the local water rate were used to calculate the potable water cost for the smart plot and control plot. These two costs were compared to evaluate overall reduction in water cost. Specific details relating to the equations and data that were used to calculate the reduction in potable water cost are provided in Section 3.2.

Assessment Criteria:

- *If* the reduction in potable water costs between the smart plot and the control exceeded 50%, *then* the smart water conservation system was considered to have achieved this performance objective.
- *If* the reduction in potable water cost between the smart plot and the control was less than or equal to 50%, *then* the smart water conservation system did not achieve this performance objective.

Results: The smart water conservation system reduced potable water cost by 81% when compared to the control plot.

6.2.1 Data Analysis, Interpretation and Evaluation:

The reduction in potable water cost for the 2-year demonstration study was based on the percent difference of the total cost of the water applied to the smart plot compared to the total cost of water applied to the control plot. The cost of the smart plot includes the cost of electrical power used to

pump water from the harvest tank (i.e., rainwater and condensate water as well as potable make-up water) to irrigate the smart plot and the cost of potable make-up water which maintains irrigation, when rainwater and condensate water are consumed (as well as ensuring the irrigation pump is protected from running dry). Consequently, the data required to determine cost are the same volumetric and pump runtime information used to determine the reduction in potable water. The pump runtime was determined using the total volume divided by the irrigation pump flowrate. The unit cost of water fluctuates from year to year; however, for calculation purposes, the installation's 2010 water rate of $6.54 per 1,000 gallons was used in the calculation. The potable water added as make-up water to the harvest tank for the smart plot was 12,843 gallons at a cost of $83.99. The electrical cost to pump water during the 2-year demonstration period was determined using the entire volume of water applied on the smart plot. The electrical cost to pump the entire 30,108 gal was $2.90. The total potable water applied on the control plot during the 2-year demonstration period was 66,653 gal at a cost of $435.92.

- The control plot used approximately 33,327 gal of total or potable water per year, equating to 52 inches of water on the 1,034 ft^2 plot at a cost of $0.21 per ft^2 per year.
- The smart plot required:
    - Approximately 15,054 gal of total water per year on the same size area, equating to 23 inches of water on the same size plot at a cost of $0.10 per ft^2 per year.
    - Approximately 6,424 gal of potable water per year on the same size area, equating to 10 inches of water on the same size plot at a cost of $0.04 per ft^2 per year.

Excluding the upfront capital cost of designing and installing a harvest tank, the smart water conservation system has the potential to substantially reduce water cost in southern California compared to the cost of utilizing a traditional irrigation system.

Some installations may realize additional cost savings where wastewater treatment charges are based on billed water use. However, this is not the case at NBVC, as irrigation water is metered separately or otherwise excluded from the sewage fee calculations.

6.3 Economic Payback

Data was collected, as discussed in Section 3.3, to assess economic payback of the smart water conservation system. The comparison included evaluating direct and indirect cost data associated with installing the smart water conservation system. The economic payback was considered the time period within which the discounted future savings of the smart water conservation system repays the initial investment costs. The future savings were determined based on a comparison of the annual reduction of potable water used and the associated cost (as compared to the traditional irrigation system) and any reduction in annual maintenance costs associated with operating the smart water conservation system. The calculation of payback was based on a present worth evaluation of the annual cost savings, assuming that interest was compounded continuously at a discount rate of 4%. The economic payback period equaled the point at which the present worth of the annual cost savings exceeded the upfront direct and indirect cost of installing the smart system.

Assessment Criteria:

- If the present worth cost evaluation demonstrated that the economic payback of the smart plot was less than or equal to 20 years, then the smart water conservation system was considered to have achieved this performance objective.
- *If* the reduction in potable water cost between the smart plot and the control was greater than 20 years, *then* the smart water conservation system did not achieve this performance objective.

Results: The payback period for the smart water conservation system was 53 years.

6.3.1 Data Analysis, Interpretation and Evaluation

Two major factors that impacted the overall cost and payback period of the smart water conservation system are: 1) the cost of the water harvest system and 2) the cost of potable water.

The cost of water is set by the regional water agency and varies throughout the DoD. Prices range on average from $1.30 per 1,000 gallons in eastern states to over $6.00 per 1,000 gallon in the southwestern states. There are extremes as well, for example the Presidio in Monterey pays $9.20 per 1,000 gallons and Fort Irwin is expected to pay up to $16 per gallon. Water rates are artificially held at the cost to produce and deliver, so all citizens have reasonable access to life-sustaining water. Consequently, the water rate has changed very little in the last few decades relative to other commodities and, for the most part, is considered undervalued.

Future water restrictions are highly likely due to population growth, depleted source waters, and climate changes that should also factor into the decision of installing a water harvest system (i.e., other than economic feasibility alone). Water scarcity in the drought-prone Southwest may override any economic goals for securing a 20-year payback period. At a minimum, the data detailed in Section 7.0 demonstrates a reasonable payback period for installation of the smart controller technology and should be implemented at facilities with substantial landscape requirements.

The capital cost of the smart water conservation system including material and installation was $75,000. The actual cost data for the sub component of the smart water conservation system has a significant impact on the economic payback period. As illustrated in Figure 20, the water harvest system is by far the most expensive component of the system. Its overall contribution to saving potable water is impacted by regional climate. In Port Hueneme, California, very little rainfall occurs from May through September, as shown during the 2-year demonstration period. To take full advantage of a water harvest system, a designer would have to maximize the size of the tank to carry the water as far into the summer months (i.e., May through September) as possible. The American Rainwater Harvesting Association highlights tank cost from $0.50 to $4.00 per gallon. Unfortunately, the cost of a tank at the Port Hueneme site is at the higher end of the range.

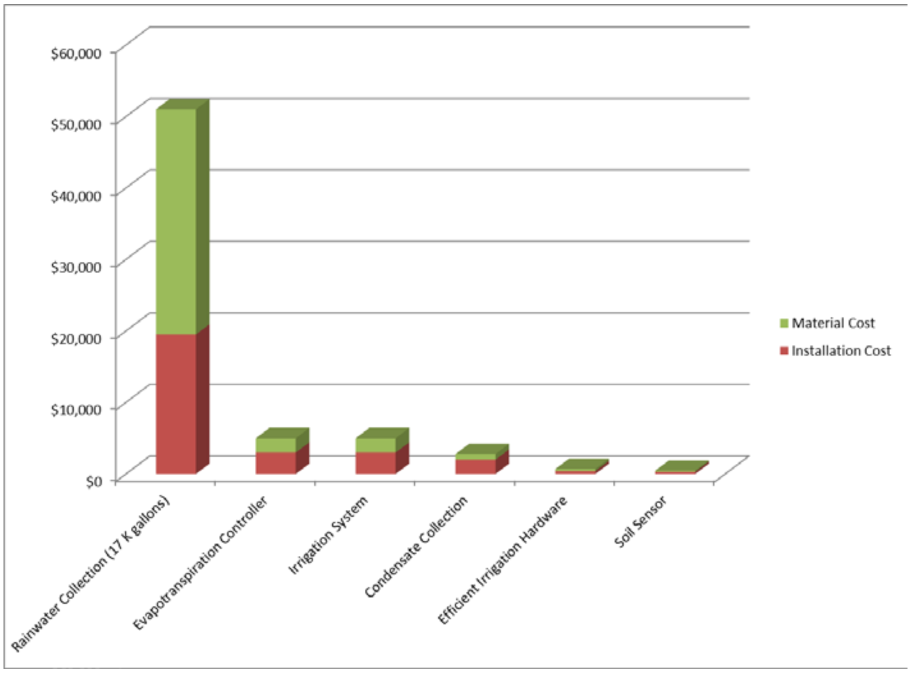

Figure 20. Costs of Components Used in the Smart Water Conservation System

Figure 21 shows that the condensate water harvesting component of the system complements the rainwater harvesting, particularly during the summer months. Notably, condensate water production in July 2014 was 3,990 gal, which could have supported all irrigation needs of the smart turf plot during the same month (i.e., required 3,846 gal). If the rainwater harvest component was determined to be feasible at a site, then installing a gravity feed HVAC condensate pipeline to the rainwater harvest tank would also make sense, as it is a relatively inexpensive additional cost.

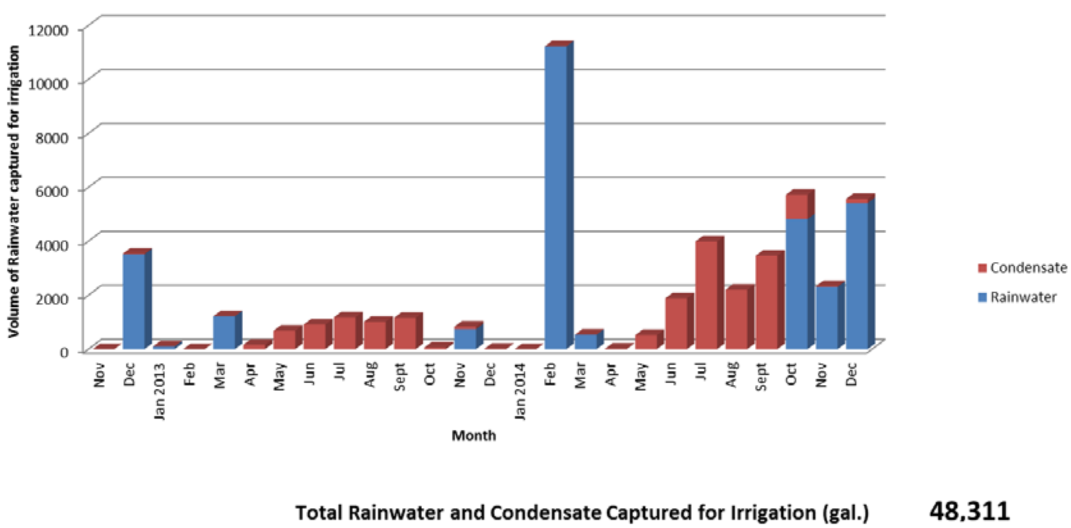

Figure 21. Amount of Rainwater and Condensate Captured during the Demonstration

6.4 Overall Energy Use Reduction

Electrical energy use data were collected and analyzed at project conclusion. As discussed in detail in Section 3.4, the energy consumption data was compared to the calculated value of pumping and treating potable water used to irrigate the control plot.

Assessment Criteria:

- *If* the total energy reduction of the smart water conservation system was 40% greater than the energy consumption associated with the traditional system, *then* the smart water conservation system was considered to have achieved this performance objective.
- *If* the total energy reduction of the smart water conservation system was less than 40% or equal to the energy consumption associated with the traditional system, *then* the smart water conservation system did not achieve this performance objective.

Results: The system achieved a 57.4 % reduction in energy use as compared to the control plot.

6.4.1 Data Analysis, Interpretation and Evaluation

The reduction in energy for the 2-year demonstration was based on the percent difference of the energy used on the control plot compared to the energy used on the smart plot. The calculation detailed in Section 3.4 highlights the cost data used which are directly tied to the volume of water applied to both plots and pump cost. The energy or electrical cost of the smart plot includes the cost of electrical power used to pump water from the harvest tank (harvested rain and condensate water as well as potable make-up water) and the electrical cost associated with purchasing the water from MWDSC. The calculations using the collected volume data along with published energy data provide a straightforward comparison. Pumping on site, using captured rainwater and condensate, provides a significant energy savings. Assuming a properly selected irrigation pump, the variable that has a direct impact on energy savings is friction loss or pressure head. Maximum energy savings can be realized by on-site generation and the avoidance of unnecessary chemical treatment.

6.5 Landscape Aesthetics

As discussed previously, photographs of the smart and control plot were taken during months 1, 6, 12, 24 of the demonstration period and analyzed by turf scientists to qualitatively assess the health of the vegetation within each plot. Appendix F contains the qualitative photographs, while Figure 22 below shows photographs before and after the demonstration period. The evaluation included documentation of any degradation in aesthetics or stress and disease resulting from each respective irrigation practice. This qualitative objective (aesthetics) was measured by turf scientists using their best professional judgment on turf characteristics which is agreed upon by the turf quality standard defined by the National Turfgrass Evaluation Program. Qualitative assessments were ranked on a scale of 1 to 10.

- *If* the aesthetic assessment rating of the smart plot was greater than or equal to the aesthetic assessment rating of the control plot, *then* the smart water conservation system achieved this performance objective.

- *If* the aesthetic assessment rating of the smart plot was less than the aesthetic assessment rating of the control plot, *then* the smart water conservation system did not achieve this performance objective.

Results: Slightly diminished appearance but acceptable aesthetics for the smart plot were observed when compared with control plot. The turf experts from California State University Fresno assigned a turf quality assessment rating of 7 for both smart and control plot at the start of the test. A turf quality of 6 was assessed for the smart plot after the demonstration was concluded. The control plot was assigned a rating of 7 after the demonstration was concluded.

6.5.1 Data Analysis, Interpretation and Evaluation

Appendix F illustrates the wide shots and close-up shots, respectively, of the control plot and smart plot during the demonstration study period. These photographs were compared and evaluated by turf experts from Cal State Fresno to determine the landscape aesthetics/turf health and provide an aesthetic assessment rating. Figure 22 provides photographs of the control plot and smart plot over time for a qualitative review of landscape aesthetics and turf health. Prior to the final assessment that was to occur after the monitoring period; the smart water irrigation pump failed which lead to turf die-off for a three week period. The expert assessment was postponed so that the pump could be fixed and turf allowed to recover for a few weeks. However the turf experts reported the tall fescue grass would have to be reseeded to recover dead spots which would bias the results. The final assessment was made in October of 2015 but as forecasted the smart plot did not rebound to the full extent. At that conclusion of the monitoring period in January 23 2015 the turf quality for both plots appeared of comparable quality.

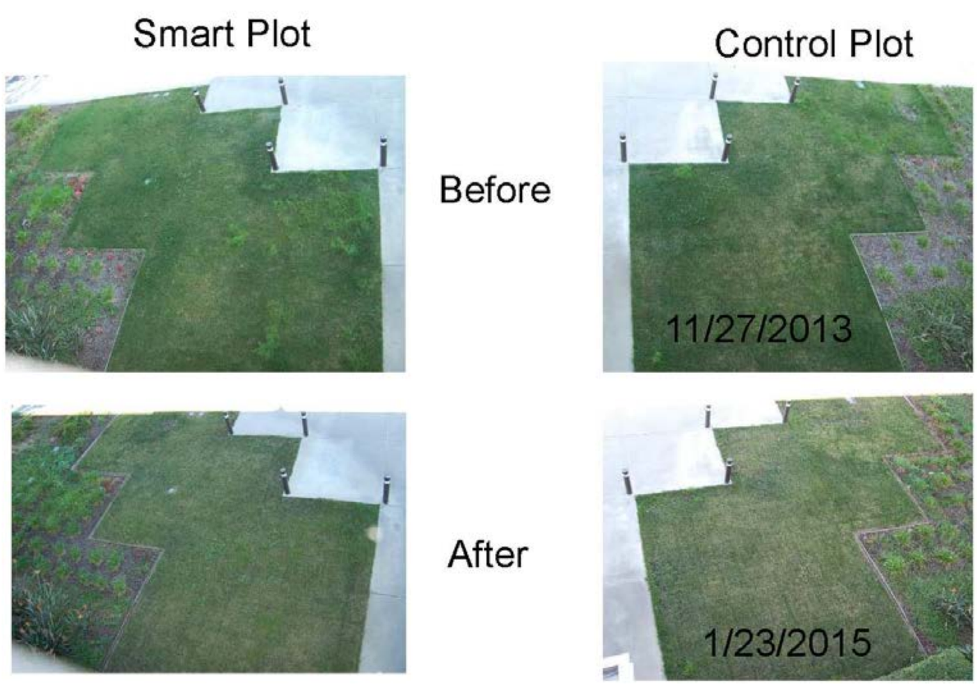

Figure 22. Qualitative Review of Landscape Aesthetics and Turf Health

7.0 COST ASSESSMENT

The cost model developed during this demonstration project serves as a means for evaluating the expected lifecycle operational cost for future deployment of the smart water conservation system. Implementing a smart water conservation system presents new capital and operating cost compared to existing irrigation practices. While effort has been made to ensure that the smart plot and control plot are comparable, site-specific factors could have a substantial impact on lifecycle cost, including weather conditions, building size [rainwater capture area] compared to landscape area, HVAC use, and water cost.

Actual costs were tracked throughout the duration of the demonstration to determine the cost-effectiveness of the system. Upon project completion, the data collected were used to estimate the lifecycle costs of this technology. Startup costs included preparing the site and installing the system. Activities such as grading, excavation, and plant removal were required to support system installation and required necessary labor and materials. System installation required labor, materials, and connection of the system to the existing electrical service. Once the system was installed, operators needed to be trained to ensure that the system is operating properly.

Additionally, maintenance and operational costs contributed to the lifecycle cost of this technology. Maintenance costs included labor, replacement parts, equipment calibration, and possibly solid waste handling and disposal. Although routine operations did not require significant labor, operations during the demonstration required additional labor due to increased data collection and analyses. In addition, costs to keep the system operational (e.g., electricity and potable water costs) were also tracked.

The site conditions for the model using Building 1100 are summarized below:

- Large footprint commercial building (125,000 ft^2)
- Centralized rooftop HVAC system
- Roof rainwater capture area (29,400 ft^2)
- Control plot and smart plot footprint (7,560 ft^2 each)
- Mediterranean climate
- Exterior wall gravity flow roof drains (partial interior)

Table 9 summarizes the actual site specific smart water conservation system cost for Port Hueneme with and without water harvest capability. Both scenarios below include the cost of upgrading an existing Calsense controller to include ET functionality with soil moisture sensor, and leak detection via flow meter.

Table 9. Cost Model for Smart Water Conservation System

Costs Model for the Smart Water Conservation System			
Cost Element	**Data Tracked during Demonstration**	**Smart Water Conservation System**	**ET Controller (Stand-alone)**
Capital costs	Vendor pricing (Taken from contract)	$75,000*	$4,995
Water cost	Utilities pricing	$6.54/1,000 gallons	$6.54/1000 gallons
Electrical cost	Utilities pricing	$0.14 per KW-hr	Not appreciable
Maintenance costs	Labor hours	$450 (10 hrs est. at $45/hr)	$90 (2 hrs est. at $45/hr)
Operator training costs	Training hours	$360 (8 hrs est.at $45/hr)	$180 (4 hrs est. at $45/hr)
Hardware lifetime	Estimate of component service life	50 years (tank) 10 years (Controller) 7 years (pump)	10 years (Controller)

*Include ET controller upgrades

7.1 Cost Model

7.1.1 Capital Costs

Capital cost is one of the most important factors in determining the feasibility of future system implementation. The equipment and installation cost for the harvest tank, the ET controller, and the pump package are primary cost drivers. The harvest tank was the most expensive component and significant time was taken to investigate options to reduce cost while maximizing the volume of storage available to collect rainwater. Commercial storage tanks ranging from 5,000 to 20,000 gallons were evaluated with price ranging from $1.50 to $5.00 per gallon depending on tank construction. Significant variations in price exist depending on local site conditions and installation requirements. An aboveground polyethylene tank was the least expensive option, but cost can escalate when implementing conventional seismic and wind restraints required by public works offices. The primary operational disadvantage of using a polyethylene tank is algae growth within the stored water, which is detrimental to sprinkler systems.

A 17,000 gallon modular polyethylene UST was selected primarily for shallow depth which was a site constraint along with multiple potential configurations and decreased potential for algae growth. The UST size was determined based on landscape area, roof size, annual rainfall, and irrigation demand. Appendix D provides a spreadsheet to aid UST sizing and design. Discounts or rebates provided by local organizations to promote water conservation were not included in the cost model.

For this model, an underground system with an estimated cost of $1.75 per gallon was initially chosen; however, the actual cost escalated to $3.23 per gallon. Table 10 provides a summary of the material and labor cost to install the UST.

Table 10. Underground Tank Cost Summary

Nomenclature	Total Cost	Notes
Materials		
6” Sand Base Layer	$503.00	Sand sub-base required below tank and liner
Geotextile Fabric	$1,710.00	Required to strengthen cap for H-20 loading
36 Mil Polypropylene Liner	$5,712.00	Required to contain water (includes installation of liner)
Poly Modules (qty. 280)	$22,764.56	Structural element of underground tank
Manholes	$823.00	Required to install pump and float valves
Materials Total	***$31,512.56***	
Labor		
Excavation	$3,179.00	Required for underground installation
Backfill	$1,808.25	Backfill for cap and sidewalls to support structural elements
Installation of Tank Inlets and Outlets	$1,200.00	Required for rainwater intake and pump outlet
Tank Module Assembly/Installation	$12,000.00	Labor estimate
Soil Cartage	$1,316.00	Required for retrofit
Labor Total	***$19,503.25***	
Shipping Total	***$1,375.00***	
Total Cost	**$52,390.81**	**$3.13 Cost per gallon**

* 280 modules are approximately 16,755 gallons.

The second largest cost was the ET controller components and a summary of the component cost is provided in Table 11. For clarification purposes, Building 1100 was originally outfitted with a Calsense controller, but not configured for advanced control using an ET gage, or the soil moisture sensor installed in the smart turf plot.

Table 11. Capital Cost for ET Controller and Accessories at Building 1100

Nomenclature	Unit cost	Exist.Equipment on-site at Building 1100 or on Base	Retrofit Building 1100
Model ET 2000e 6 Station	$3,950.00	Yes	$0.00
Stainless Enclosure W/ Dome Antennae and Transient protection	$2,360.00	Yes	$0.00
ETg Interface	$475.00	Yes	$0.00
Rain Bucket Interface	$475.00	Yes	$0.00
Transient Protect Package	$735.00	Yes	$0.00
ET Gauge	$1,375.00	Yes	$0.00
Stainless Steel Enclosure for ET gauge	$995.00	Yes	$0.00
Calsense Tipping Rain Bucket	$595.00	Yes	$0.00
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna	$190.00	No	$190.00
Communication (Phone line/Ethernet Device)*	$925.00	NA	$0.00
Communication Hub	$1,850.00	Yes	$0.00
Dash F Option Additional meter/valve interface	$1,000.00	No	$1,000.00
Installation (estimated)			$3,000.00
			$4,995.00

* Currently not available to DoD due to IT restrictions but used extensively in the private sector.

7.1.2 Installation Costs

Installation costs were comprised of the labor hours needed to retrofit the existing irrigation system and install a water harvesting and pump system. The major labor requirement was for the rainwater harvesting components and pump system. Installation included replacement of component parts and rerouting the facility HVAC and rooftop drainage to flow into the harvest UST. For this cost element, the total number of labor hours to install the water harvesting and pump system was captured from the contractor cost proposal.

7.1.3 Water Cost

Water purchased from the Port Hueneme Water Agency and United Waters has fluctuated in price over the last several years. The cost of potable water used for irrigating the landscape at Building 1100 was $6.66 per 1,000 gallons in 2011. The average unit cost over the last four years (FY2008 to FY2011) is $6.95 per 1,000 gallons. For purposes of the cost model the lowest rate occurring at FY 2010 of $6.54 per 1,000 gallons will be used. Actual water costs for Building 1100 over the last four years are as follows:

- FY2008 $7.09/1000gallons
- FY2009 $7.49/1000 gallons
- FY2010 $6.54/1000 gallons
- FY2011 $6.66/1000 gallons

7.1.4 Electrical Cost

Electrical power is required to run the controller, sensors, and irrigation pump. The cost model includes the electrical cost to operate the system, which is $0.14 per kilowatt hour based on unit

electrical cost information from 2011. The power requirements for the controller and sensors were considered insignificant and were calculated instead of from direct metering and then were added to the overall utility cost. The pump was outfitted with a flow meter to calculate the kilowatt hours (based on pressure, and estimated pump and motor efficiency) used throughout the 2-year demonstration period. The total cost of operating the pump is included in the cost model.

7.1.5 Maintenance Costs

Maintenance costs were the expenditures incurred for any repairs, troubleshooting, and similar maintenance calls necessary for the smart water conservation system to operate properly. Similar to installation costs, maintenance costs were tracked throughout the demonstration period. This included tracking costs for labor hours and costs for needed parts. Labor costs were assumed at $45 per hour for the cost model.

7.1.6 Operator Training Costs

Operator training costs were the labor costs required for the landscape manager to familiarize oneself with the controller and any unique hardware. Familiarization included making basic program changes and troubleshooting. Training costs were determined by tracking the labor hours used for reviewing product literature multiplied by the hourly rate. Labor costs were assumed at $45 per hour for the cost model. To note, operator training should only occur once during the lifecycle of the system for each operator.

7.1.7 Lifecycle Costs

The lifecycle costs of the smart water conservation system combined capital costs, installation, maintenance, and yearly operations costs. It was expected that the life of the smart water conservation system ranged from 10 to 15 years, with the exception of the UST which can last up to 50 years.

The procurement and installation of the individual system components were a one-time cost. Maintenance and operator costs were based on required annual maintenance, such as filter change-outs and tank cleaning. Most of the sprinkler hardware offered by Rain Bird® has a warranty of two to three years, depending on the component. Any repair or replacement of components during their respective warranty periods did not incur associated costs; however, labor hour costs were incurred to conduct the repair/replacement.

7.2 Cost Drivers

The most significant cost drivers for the implementation of the smart water conservation system at a potential deployment site are the cost of a water harvest storage tank and the cost of potable water. The cost of the storage tank is directly linked to its size and composition. Determining the proper tank size for a specific site is a challenge, as there is no simple strategy that links tank sizing for irrigation with economic viability. An iterative economic analysis must be performed as highlighted in Section 7.3 that takes into account tank size based on site average monthly rainfall data, roof area, and irrigation demand (based on turf type area and average monthly ET) with the cost of potable water. Several tank sizing guidance strategies were considered that can be employed as a starting point to evaluate economic feasibility. Figure 23 provides the various tank

size options considered for Port Hueneme based on roof area, average monthly rainfall, and turf area if the entire smart plot was 7,560 square feet. Ultimately, the tank at Port Hueneme was sized based on EISA Section 438 of 2007, managing on-site the total volume of rainfall from the 95th percentile storm, which was approximated at 20,000 gallons storage capacity.

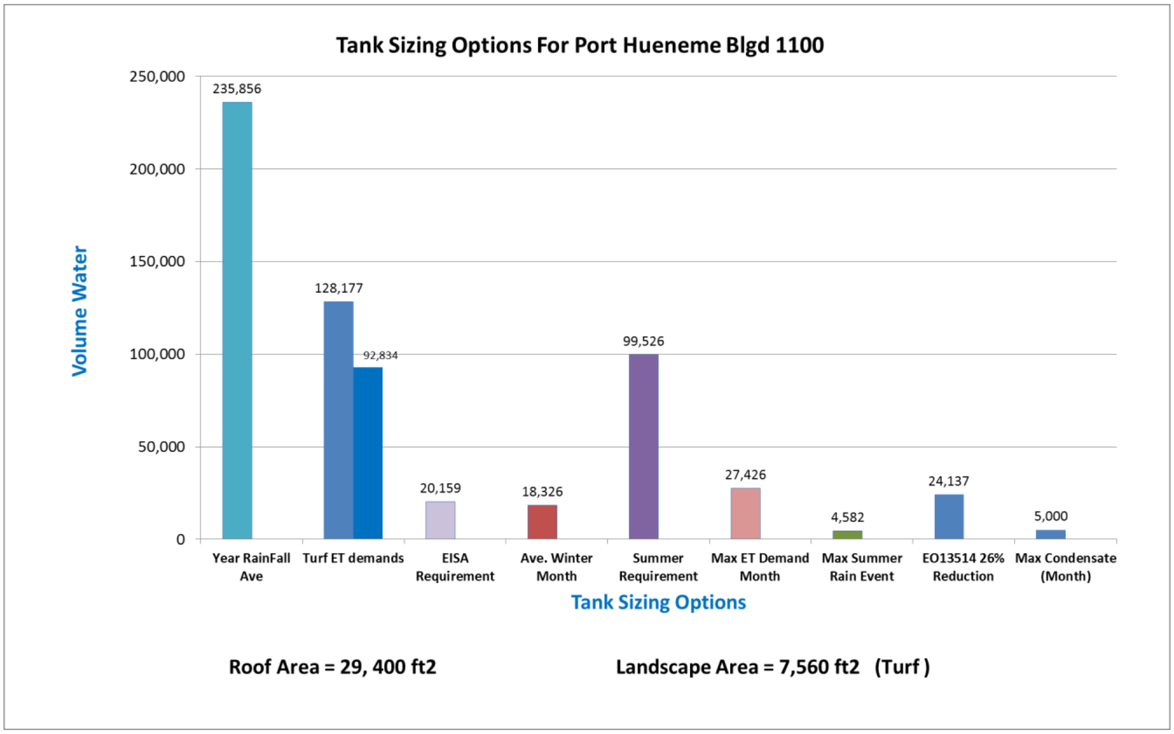

Figure 23. Tank Sizing Options for Building 1100

As mentioned earlier, discussions with facility manager and the site conditions dictated a below ground tank over the above ground tank. However, each type has been implemented for water harvesting in drought areas in Texas and California. Each type of tank has unique site-specific implementation requirements that increase cost.

Site-specific cost considerations for the underground tank implementation include:

- Determining the existence of underground utilities (retrofit concern)
- Installing sub foundation and cover
- Excavation, and landscape and tree removal (retrofit concern)
- Disposing of excavation spoil (retrofit concern)
- Engineering and design for high groundwater

Site-specific cost considerations for the above ground tank implementation include:

- Engineering and design for seismic and wind loads
- Installing foundation

- Anchoring restraint system for seismic and wind load
- Equipment cost (Crane support for larger tanks)

Overall, the cost of potable water compared to the cost savings resulting from water harvested must be considered before installing any tank. Accordingly, a sensitivity analysis was performed illustrating the cost of potable water compared to the amount of water harvested by the system. Given a potable water cost at $6.54 per 1,000 gallons, tank cost would have to be less than $0.50 per gallon to provide a payback at the established 20 year period. If current tank costs were held at $3.13 per gallon, then potable water costs would have to be $34 per 1,000 gallon to meet the 20-year performance objective. The ideal geographic area to install and implement the entire smart water conservation system are areas such as Tucson, Arizona and Fort Hood, Texas which receive summer monsoonal rains that can replenish the water harvest tank during the summer months when demand is greatest. In addition, they are also known to generate large amounts of HVAC condensate. In areas such as southern California, the goal is to install the largest tank possible to irrigate as long into the summer as possible. However, the economics do not indicate that there is a reasonable return on investment.

7.3 Cost Analysis and Comparison

Tables 12 through 15 summarize system payback for three (3) different scenarios on a typical administrative facility surrounded by irrigated turf. Building 1000, found at NBVC was chosen for the analysis and comparison as it has substantial turf area and could benefit from a smart water conservation system. The building was constructed in 1994, has a roof area of approximately 23,600 ft^2 and turf area of approximately 35,000 ft^2. The turf is currently irrigated with a traditional, timer-based irrigation system. Appendix G provides notes on the ROI worksheet of how each input value was derived or its source reference.

Scenario 1: DoD building with turf retrofitted with Smart ET controller.

Scenario 1 is the retrofit of an existing operational building replacing a timer based controller with a Calsense controller. This scenario assumes that a new Calsense ET controller will be installed at an estimated cost of $12,000.

Appendix H presents a cost break down of different options and communication configurations related to the controller. For this scenario the water harvest tank size is 0 gallons and all harvest tank related costs are $0. The facility was built at a time when there was minimal interest in water efficient landscape. The ROI is less than 6 years for retrofitted installations.

Table 12. Scenario 1 Cost Estimates

SITE CONDITIONS/ASSUMPTIONS	Data	UNITS/NOTES
Climate	Mediterranean	
Roof Area (plan view)	23,600	FT2
Turf Size	35,000	FT2
Average Rain Per year	14	Inches/year
Rainwater Available @ 50% normal	105,301	gallons
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	Inches/year
Average Summer ET requirement for Turf	21	Inches
Retrofit or New Construction	Retrofit	
HARVEST TANK INFORMATION		
Harvest Tank (Estimated Cost per gallon $1.50 -$5.00)	$0.00	Material and Installation Cost
Above ground or Below ground	Below Ground	
Estimated size of tank	0	gallons
Tank Service life	50	years
Estimate of total yearly volume of Condensate	15000	
UTILITIES UNIT COST		
Water Cost	$6.54	Cost per 1000 gallons
Electrical cost	$0.14	Cost per KW-h
SMART WATER SYSTEM COMPONENTS		
Capital Cost of Calsense Controller ($12,000)	$12,000	
Capital Cost of pump package and makuep water($4141)	$0	
Capital Cost of Water Harvest Component (Size dependent)	$0	
Capital Cost of First Flush and Ancillary (5% or Water Harvest)	$0	
Smart Oper and Maint. cost (1 hours per year)	$0	
Smart Training (One time only)	$60	
If function: No harvest tank = 0, If tank size > 0 = 1	0	
Capital Cost (Retrofit)	**$12,060**	
Capital Cost (New Construction)	**$0**	
VOLUME OF WATER NEEDED		
Average Water Demand (ET Demand -Rainwater)	20	inches
Irrigation Efficiency of Smart Water System	0.55	From Demonstration
Total water Needed for Satisfactory Turf (Timer Based)	781,433	gallons
Total irrigated water Needed for Satisfactory Turf (Smart)	429,788	gallons
Water Harvest Tank efficiency Factor	1.5	From Demonstration
Total Potable water for turf Plot	414,788	
Economic Analysis Results		
Water Cost annual increase (2% escalation)	0.02	Percentage
STATUS QUO: Timer- (Potable Water Cost Year 1)	$5,111	
SMART PLOT: (Potable Water Cost Year 1)	$2,811	Assumes that potable water is needed
SMART PLOT: (Electrical Cost)	$0	
Cost Avoidance (Year 1)	$2,300	
Water reduction (Percent) reduced by Tank	0.00%	Percentage
Payback (Retrofit)	**5.2**	**years**
Payback (New Construction)	**0.0**	**years**

Scenario 2: DoD building (Building 1000) with turf retrofitted with Smart System.

Scenario 2 is the retrofit of an operational building with the entire smart water conservation system, excluding the condensate harvesting component since the building does not have air conditioning. The water harvest tank was sized to satisfy current EISA requirements.

Table 13. Scenario 2 Cost Estimates

SITE CONDITIONS/ASSUMPTIONS	Data	UNITS/NOTES
Climate	Mediterranean	
Roof Area (plan view)	23,600	FT2
Turf Size	35,000	FT2
Average Rain Per year	14	Inches/year
Rainwater Available @ 50% normal	105,301	gallons
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	Inches/year
Average Summer ET requirement for Turf	21	Inches
Retrofit or New Construction	Retrofit	
HARVEST TANK INFORMATION		
Harvest Tank (Estimated Cost per gallon $1.50 -$5.00)	$3.11	Material and Installation Cost
Above ground or Below ground	Below Ground	
Estimated size of tank	20000	gallons
Tank Service life	50	years
Estimate of total yearly volume of Condensate	0	
UTILITIES UNIT COST		
Water Cost	$6.54	Cost per 1000 gallons
Electrical cost	$0.14	Cost per KW-h
SMART WATER SYSTEM COMPONENTS		
Capital Cost of Calsense Controller ($12,000)	$12,000	
Capital Cost of pump package and makuep water($4141)	$4,141	
Capital Cost of Water Harvest Component (Size dependent)	$62,200	
Capital Cost of First Flush and Ancillary (5% or Water Harvest)	$3,110	
Smart Oper and Maint. cost (1 hours per year)	$50	
Smart Training (One time only)	$60	
If function: No harvest tank = 0, If tank size > 0 = 1	1	
Capital Cost (Retrofit)	**$81,561**	
Capital Cost (New Construction)	**$0**	
VOLUME OF WATER NEEDED		
Average Water Demand (ET Demand -Rainwater)	20	inches
Irrigation Efficiency of Smart Water System	0.55	From Demonstration
Total water Needed for Satisfactory Turf (Timer Based)	781,433	gallons
Total irrigated water Needed for Satisfactory Turf (Smart)	429,788	gallons
Water Harvest Tank efficiency Factor	1.5	From Demonstration
Total Potable water for turf Plot	399,788	
Economic Analysis Results		
Water Cost annual increase (2% escalation)	0.02	Percentage
STATUS QUO: Timer- (Potable Water Cost Year 1)	$5,111	
SMART PLOT: (Potable Water Cost Year 1)	$2,615	Assumes that potable water is needed
SMART PLOT: (Electrical Cost)	$52	
Cost Avoidance (Year 1)	$2,393	
Water reduction (Percent) reduced by Tank	6.98%	Percentage
Payback (Retrofit)	**34.1**	**years**
Payback (New Construction)	**0.0**	**years**

Table 13. Scenario 2 Cost Estimates (cont.)

EISA Tank Size Determination		
Roof size	23,600	FT2
95 percentile Storm (30 year Period)	1.1	Inches -Historic Information
Tank Volume per EISA Requirment	16,182	Gallons

PUMP COST (Smart Water)		
Volume of water pumped	501,783	gallons
Hours of operations	643	Hours
Flow rate	13	gpm
Pump Efficiency	0.6	
Motor Efficiency	0.6	
Horsepower	1	HP
Pressure Head	100	Feet
Pump cost per hour (Calculated)	$0.10	
Pump cost per year (Calculated)	$61	

Scenario 3: DoD building (Building 1000) with turf assumed new construction with Smart System.

Scenario 3 is new construction of Building 1000, holding constant the existing size of both the building and turf area, and installing both the smart ET controller and water harvesting component. The building does not have an air conditioning unit but for this analysis the condensate harvesting is included. The water harvest tank was sized to concurrently satisfy current EISA requirements for storm water management using a cistern. Accordingly, cost of the tank is mostly covered by the requirements to satisfy capturing the 95% storm event and not included in the costs to calculate payback time. The irrigation system would be the same as that used at the demonstration site and consists of about 20 irrigation zones. However, the analysis includes the capital cost of the pump and potable make-up water system. Only about two of the irrigation zones would be outfitted with purple pipe for coverage by the harvested water, as tank capacity can only match irrigation demand for approximately 2 zones. The ROI is less than 11 years for new construction installations.

Table 14. Scenario 3 Cost Estimates

SITE CONDITIONS/ASSUMPTIONS	Data	UNITS/NOTES
Climate	Mediterranean	
Roof Area (plan view)	23,600	FT2
Turf Size	35,000	FT2
Average Rain Per year	14	Inches/year
Rainwater Available @ 50% normal	105,301	gallons
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	Inches/year
Average Summer ET requirement for Turf	21	Inches
Retrofit or New Construction	New Construction	
HARVEST TANK INFORMATION		
Harvest Tank (Estimated Cost per gallon $1.50 -$5.00)	$3.11	Material and Installation Cost
Above ground or Below ground	Below Ground	
Estimated size of tank	20000	gallons
Tank Service life	50	years
Estimate of total yearly volume of Condensate	15000	
UTILITIES UNIT COST		
Water Cost	$6.54	Cost per 1000 gallons
Electrical cost	$0.14	Cost per KW-h
SMART WATER SYSTEM COMPONENTS		
Capital Cost of Calsense Controller ($12,000)	$12,000	
Capital Cost of pump package and makuep water($4141)	$4,141	
Capital Cost of Water Harvest Component (Size dependent)	$59,090	Cost of tank not included in Capital cost*
Capital Cost of First Flush and Ancillary (5% or Water Harvest)	$2,955	
Smart Oper and Maint. cost (1 hours per year)	$50	
Smart Training (One time only)	$60	
If function: No harvest tank = 0, If tank size > 0 = 1	1	
Capital Cost (Retrofit)	**$0**	
Capital Cost (New Construction) *	**$25,115**	
VOLUME OF WATER NEEDED		
Average Water Demand (ET Demand -Rainwater)	20	inches
Irrigation Efficiency of Smart Water System	0.55	From Demonstration
Total water Needed for Satisfactory Turf (Timer Based)	781,433	gallons
Total irrigated water Needed for Satisfactory Turf (Smart)	429,788	gallons
Water Harvest Tank efficiency Factor	1.5	From Demonstration
Total Potable water for turf Plot	384,788	
Economic Analysis Results		
Water Cost annual increase (2% escalation)	0.02	Percentage
STATUS QUO: Timer- (Potable Water Cost Year 1)	$5,111	
SMART PLOT: (Potable Water Cost Year 1)	$2,517	Assumes that potable water is needed
SMART PLOT: (Electrical Cost)	$52	
Cost Avoidance (Year 1)	$2,492	
Water reduction (Percent) reduced by Tank	6.98%	Percentage
Payback (Retrofit)	**0.0**	**years**
Payback (New Construction)	**10.1**	**years**
* Cost of tank not included in Payback calculation.		

In Summary, Scenario 1 would be the easiest to implement and has the shortest payback time (i.e., at 5.2 years). With a payback time of 34.1 years, Scenario 2 would be the least favorable option due to its minimal cost effectiveness for reducing potable water use for landscape irrigation in southern California. Leveraging the EISA requirement to manage water with cisterns in future building construction, Scenario 3 may be practical way to justify the implementation of a smart water conservation system as it has a favorable payback.

In general, due to the high cost of retrofitting a water harvesting system and the relatively short rainy season (and mostly dry summer season) in southern California, it is not a cost effective method to reduce potable water usage for landscape irrigation. Drought prone area like Tucson Arizona, and Killeen Texas have consistent rain in the summer due to monsoonal weather pattern may have a better payback. In the scenarios above using water harvesting systems, the harvesting system accounts for about 7% of the water used for irrigation. However, as water costs increase and regulations limit the amount of potable water that can be used for irrigation purposes, the viability of using water harvesting systems will increase.

8.0 IMPLEMENTATION

In some regions of the United States, where water use is more highly regulated due to drought conditions and general water scarcity, implementation of water-saving systems is becoming a necessity. In regions where water is scarce, cost and ease of implementation and operation and maintenance requirements are evaluated to determine whether implementation of water harvesting or smart water conservation systems are feasible options. This section presents the regulations, end use, procurement issues, and lessons learned identified during the demonstration study. Appendix I provides a generic discussion of technology transfer tools and methods to be considered for the implementation this technology.

8.1 Pertinent Regulations, Executive Orders, Codes and Standards

There are no federal regulations, codes, or standards for implementing rainwater harvesting systems or ET controllers on DoD installations; however, the following guidance manuals may serve DoD utility managers considering installation of a system:

- Rainwater Harvesting for Army Installations
- Guideline for Estimate Unmetered Landscape Water Use (FEMP)
- Low Impact Development Unified Facilities Criteria
- Watergy: A Water and Energy Conservation Model for Federal Facilities
- Green Plumbing and Mechanical Code Supplement

The majority of regulations that do exist are found at the state and local level. There has been little consensus among the regulators with regards to standard plumbing and maintenance of smart water conservation systems, especially in the water harvesting components. However, some states have provided their own guidance manuals on water harvesting and basic minimum standards.

Local regulations in some drought prone areas of the southwest require new residential and commercial facilities construction to capture roof rainwater (requiring 50% of the properties irrigation to be supplied by rainwater). Some local governments have also enacted restrictions on watering days and irrigation runtime and require implementation of smart irrigation controllers with turf landscape. Federal facilities are not required to follow local regulations; however, EO 13693 requires federal agencies to install appropriate green infrastructure features on federally-owned property to help with stormwater and wastewater management and many federal facilities have enacted their own water conservations regulations.

The International Association of Plumbing and Mechanical Officials recently published the Green Plumbing and Mechanical Code Supplement that establishes requirements for green buildings and water efficiency applicable to plumbing and mechanical systems. It typically refers to the "Authority having Jurisdiction" for matters of permitting and approvals. The code provides provisions for non-potable rainwater collection systems, including collection surfaces, storage structures, pipe labeling, air gaps, and other design criteria.

The American Rainwater Catchment System Association provides guidance for design of safe rainwater catchment systems and applications of harvested water including potable, non-potable,

and fire protection uses. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers Green Guide serves as a reference for green building design that includes rain water harvesting. In addition, the Texas Manual on Rainwater Harvesting gives end user basic information for rainwater harvesting.

As mentioned in Section 1.3, the primary federal regulatory driver for this demonstration project is EO 13693, which requires federal agencies to improve water use efficiency and management. Since landscape irrigation often represents one of the largest demands of potable water at DoD facilities, smart water conservation systems can make significant progress at the achieving the EO 13693 guidelines.

8.2 End User Concerns

8.2.1 Maintenance and Ownership

End users will have to budget to provide manpower to maintain the smart water conversation system. Most of the maintenance is required on the water harvesting tank and the first flush diverter. The maintenance is not considered exorbitant, but routine action must be performed at a minimum frequency. Table 16 provides suggested maintenance procedures so that a budget can be determined by appropriate facility managers. Pumps will fail over time and the facility owner should budget for one (1) new pump every 5 years. It would be advisable to procure a backup pump that is available throughout the year in the event of a pump failure.

Table 15. Recommended Maintenance Schedule for Water Harvest System

Activity	Frequency
Clean out First Flush Diverter	Once per year
Check Mosquito Screens	Once per year
Inspect Tank for Sediment	Once every 3 years
Inspect Tank for Leaks	Once per year
Clean Tank	Once every 5 years
Pump Replacement (estimated 4-7 years)	Once every 5 years

Implementation of a smart water conservation system requires a dedicated staff to take ownership of the technology. If ownership is not addressed, like any system, the technology can easily become dysfunctional. Accordingly, if a group or individual is not assigned at the onset to fully learn the system and perform routine maintenance, the system will not perform as designed. Adjustments to the controller settings based on site conditions are required throughout the first year to maximize lifecycle savings.

8.2.2 Tank Leaks

Tanks losing make-up water would defeat the overall purpose of the smart water conservation system, which is to reduce potable water use and associated energy. All tank systems have the potential to leak, but, with proper installation, the polyethylene material used to encapsulate the

tank modules will hold up for years underground. A well designed and constructed tank can be leak-free for up to 30 to 50 years. During the course of the 2-year demonstration period, the only leaks discovered were found during the initial hydrostatic test and were found at the top levels of the UST near the inlet and outlet pipe penetrations. The leaks were measured by tracking water level over the course of several days. Leakage only occurred in the wet season and was determined to be less than 1 inch drop over a 1-week period (or 50 gallons per day) and only at the top levels of the UST. Penetrations for pipeline or conduits are recommended to be as high up on the sidewall or top of the tank, if site conditions permit. Small leaks at the top of the tank can be tolerated during the wet season when water demand is at its lowest.

The following practices used in the construction of the system are also recommended:

1. Conduct full height hydro testing on tank liner before tank acceptance;
2. Use a minimum 35-mil polyethylene liner instead of the 24-mil typically used for retention basins;
3. Shop weld corners and pipe inlets instead of welding polyethylene liner in the field;
4. Place clean fill sand below tank and around sidewalls. Sand must be completely free of rocks or sharp objects and properly compacted;
5. Extra care needs to be taken to keep sharp objects, tools, etc. away from liner during installation of modules. Consider use of secondary liner on the bottom for construction foot traffic;
6. Use controller to only allow potable make-up water to fill tank 20 to 30 minutes prior to irrigation;
7. Float switch set point for potable make-up water additions should be a low as possible, but high enough to protect the pump.
8. Conduct annual leak test in the winter months to monitor the condition of the tank.

8.3 Procurement Issues

The equipment used on the smart water conservation system, with the exception of the NAVFAC developed first flush diverter, are commercially available off-the-shelf components and were procured via a Broad Agency Announcement (BAA) contract. For future installation on buildings with substantial irrigated landscape and timer-based irrigation controllers, planners should consider procuring soil-based or ET controllers using a credit card, Bills of Material, or small contracts. The basic ET controller can be purchased direct or customized with options, which could take one or two weeks to build. The first flush diverters originally purchased for the demonstration project were ordered from a company in Australia through a local US distributor requiring a 2 to 3 week lead time. All other components are readily available through local sources.

8.4 Lessons Learned

Lesson learned during the demonstration of the smart water conservation system are as follows:

Site Selection Considerations:

- Use cost model to determine what level of the smart water conservation system to implement (i.e. ET controller only or ET controller with water harvest.

- Implement soil-based or ET controllers at any landscape that has a substantial turf area (≥30,000 square foot has a payback less than 6.1 years).

- Consider rainwater harvesting when one or more of the following regional conditions exist:
  - High water cost
  - Drought prone areas (water scarcity)
  - Forward Operating Bases with limited water sources
  - Regions with consistent monthly rainfall during summer months
  - Regions with consistent HVAC condensate water during summer months.
  - Areas with substantial rebates provided for rainwater harvest tanks
  - Alternate source water available (Potable water pipe flushing)
  - In new construction seeking LEED points
  - In regions that charge for stormwater discharge
  - In new construction requiring underground storage for managing stormwater EISA section 438 (applicable when soil infiltration rates are not enough)

- Implement the smart water conservation technology only with user buy-in to operate and maintain system.

Technical Detail and Logistics:

- Implement condensate harvesting if rainwater harvest is implemented, since condensate harvesting is a minimal add-on feature that will provide water during summer months.

- Operate the harvest tank irrigation pump a few times during the winter months to insure proper operation.

- Program system alarms, such as leak or no-flow condition, to alert facility managers and landscape technicians via telephone.

- Pest control practices should include laying wire in conduits and wrapping valve boxes with wire mesh.

- Consider writing landscape maintenance contracts to include a minimum maintenance frequency during periods of budget cuts, as lack of pest control, ignored system alarms, and overgrown turf and shrubs can have a profound impact on sprinkler distribution systems, turf quality, and limit the overall usefulness of a smart water conservation system.

See appendices J and K for additional lessons learned at the smart water conservation system installed at Fort Hood, Killeen Texas. The system installed at Fort Hood used an above ground tank for harvesting rainwater and condensate

8.5 First Flush

The first flush of a rain event must be considered when implementing the roof rainwater harvesting component of the smart water conservation system, as its quality can have an adverse impact on system functions. Debris from the roof material itself (physical and chemical degradation), wind-blown contaminants, bird droppings, and other organic materials are typically concentrated in the first flush. Particles in a specific size range can foul the operations of the nozzles, clog the inlet filters at the sprinkler heads, and otherwise negatively impact the sprinkler efficiency. Once in the plumbing system, the particles may have an impact on maintenance frequency (both in the tank and sprinkler system), uniformity of sprinkler coverage, and water usage. In addition, flow meters, particularly paddle wheel systems, could have their accuracy impacted by particulate and biological growth, increasing the paddle wheel friction and thereby reducing paddle wheel speed. Consequently, diversion of first flush must be accomplished to reduce maintenance frequency and irrigation runtimes.

Commonly used roof material includes asphalt shingles, galvanized metals, rubber membrane, cement tile, aluminum, and soil plant mixtures (green roofs). Loose grit from asphalt shingles is typically a size that can be removed with a first flush diverter or settled out easily in the tank via gravity. The pump inlet should be placed a few inches above the tank floor to prevent particulates from entering the sprinkler system. However, it is better to remove the debris prior to entering the tank. This is done with the first flush diverter. Conventional design guidance suggests diverting 1 liter per square meter roofing for lightly loaded roofs and 2 liters per square meter for heavier loads. Buildings with significant bird droppings on the roof should consider greater diversion volumes of the first flush or applying harvested water only to underground irrigations systems. Two types of first flush diverters, constant volume-based and flow-based, diverter valve were demonstrated. The constant volume system performed better in terms of maintenance and reset for subsequent rain events.

The demonstration showed that the flow rate diverter valve design required substantial maintenance after each storm event to reset the system for subsequent storms. After some minor adjustments to allow the valve ball to drain between rain events, the problem still persisted. To resolve the reliability issue, one of the flow rate diverter valve units was replaced with a constant volume based diverter. The constant volume based system displayed greater reliability by consistently draining down after each rain event, and thus available for subsequent storm events. The design is simple and can be made with commercially available products.

Some older asphalt and wood shingle roofs have been shown to have containments such as lead, mercury, copper, and arsenic. Terra cotta and cement tiles are known to release lead, copper, cadmium, and asbestos. Planners may wish to consider taking grab samples to fully characterize the roof water prior to implementation, or consider greater diversion volumes of the first flush.

8.6 Design Considerations

Based on the lessons learned from the demonstration project, design considerations for implementing a smart water conservation system were developed. These considerations are presented in Table 17 for the rainwater harvesting system and Table 18 for the ET controller and irrigation system.

Table 16. Design Considerations for Implementing the Smart Water Conservation System

Part	Above Ground	Below Ground
Tank	Foundation design for Seismic load, Wind Load. Aesthetic concerns. Underground utilities. Select material that blocks UV to reduce algae growth. Include easy read tank level gauge. Use economic spreadsheet to determine feasibility.	Consider Buoyancy issue with ground water, Above Grade loading, H-20 loading, and underground utilities. Locate openings near areas free of debris. Use Economic spreadsheet to determine feasibility. Conduct hydro-static test before acceptance.
Rainwater Inlet	Locate near downspout. Include screen to remove sediments, leaves, and trash. Hydro-test for leaks.	Locate as high up in the tank as possible for modular tank system. Hydro-test for leaks.
Outlet	Locate near electrical power and optimum pump location. Hydro-test for leaks.	Locate as high up in the tank as possible for modular tank system. Hydro-test for leaks.
Tank Drain	Locate at lowest point in tank for efficient cleaning.	Not practical. Drain with submersible sump pump.
First Flush Diverter	First flush diverter designed to remove 1 L per square meter for light load. Remove 2 liter per square meter for heavy load. Design with automatic self-drain. If possible direct first flush water to landscape away from building foundations.	First flush diverter designed to remove 1 L per square meter for light load. Remove 2 liter per square meter for heavy load. Design with automatic self-drain. If possible direct first flush water to landscape away from building foundations.
Potable Make-up Water	Locate near water source. Control with float sensors. Ensure minimum amount of water for safe pump operations. Potable make-up water should have an Air- gap to protect potable water system. Include mosquito screen. Ensure Back flow preventer upstream.	Locate near water source. Control with float sensors. Ensure minimum amount of water for safe pump operations. Potable make-up water should have an Air- gap to protect potable water system. Include mosquito screen. Ensure Back flow preventer upstream.
Valves	Ensure valves are included to isolate system components and for leak tests.	Ensure valves are included to isolate system components and for leak tests.
Mosquitos Screens	Apply on all opening on tanks as appropriate, including potable make-up water port.	Apply on all opening on tanks as appropriate, including potable make-up water port.
Overflow Port	Direct overflow to French drains, if possible. Otherwise to storm drain.	Direct overflow to French drains, if possible. Otherwise to storm drain.
Pump Package	Use adjustable check valve to prevent anti-siphoning. Design for proper flow and pressure. Include an easy access gross filter. Pump inlet 4”-6” above tank floor. Design for easy pump removal for repair or replacement.	Use adjustable check valve to prevent anti-siphoning. Design for proper flow and pressure. Include an easy access gross filter. Pump inlet 4”-6” above tank floor. Design for easy pump removal for repair or replacement. Install liner protection below pump to prevent leakage.

Table 17. Design Considerations for ET Controller and Irrigation System

Part	Design Consideration

Condensate Capture	If redirecting condensate from sanitary sewer, ensure sewer gases are managed.
Pipeline	Use purple line for irrigation system or bury with appropriate “not for human consumption” yellow tape. Design pipe system for minimum head loss. Bury below frost line. Include port to purge water with compressed air during winter months.
ET Controller	Consider implementing ET controller for all substantial landscape turf and ground cover. Irrigation cycle time must account for non-uniform water coverage. Overwater initially in the spring/early summer to determine optimum irrigation safety factor. Irrigate at night or early morning. Set soak and cycle for clay soils.
ET Sensor	Locate in area that is representative of turf area.
Soil Sensor	Bury at manufacturer recommended depth. Bury in an area that receives representative sun. If possible, protect from gophers.
Rain Gauge	Program controller to prevent/stop irrigation during a rain event.
Flow Meter	Apply on mainline. Use with controller to identify out of range flowrates. Set up alerts to warn operators if out of spec flowrates.
Efficient Sprinkler System	Ensure proper head to head sprinkler spacing. Maximize sprinkler coverage and uniformity. Use long nozzle if maintenance will be an issue.
Pressure Regulating Valve	Use to minimize overspray and optimize flowrate.
Turf Lawn	Conduct annual irrigation audit. Use drought tolerant plant species. Conduct routine maintenance to prevent sprinkler trajectory blockage.
Ground Covers	Use rotary heads. Landscape with drought tolerant plant species.
Winterize	Develop a customized winterize plan. See Appendix K for example.

9.0 REFERENCES

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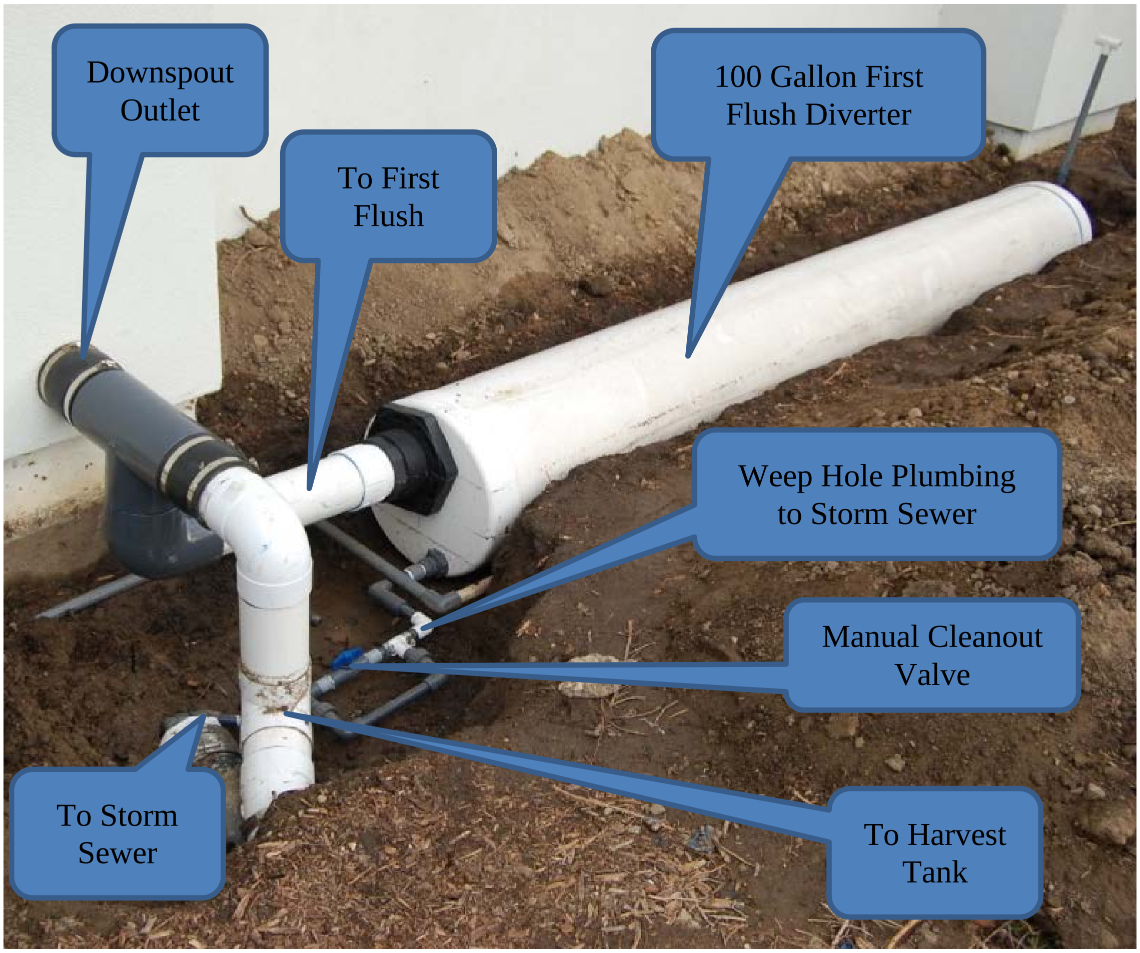
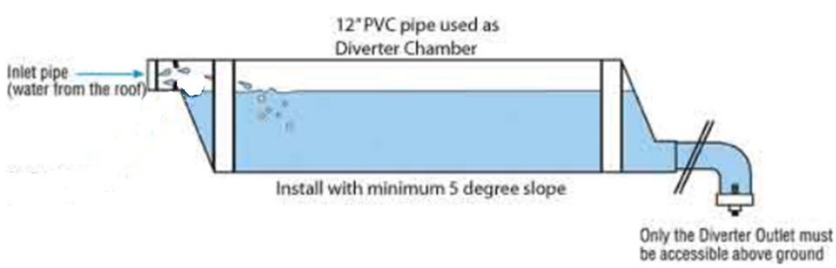
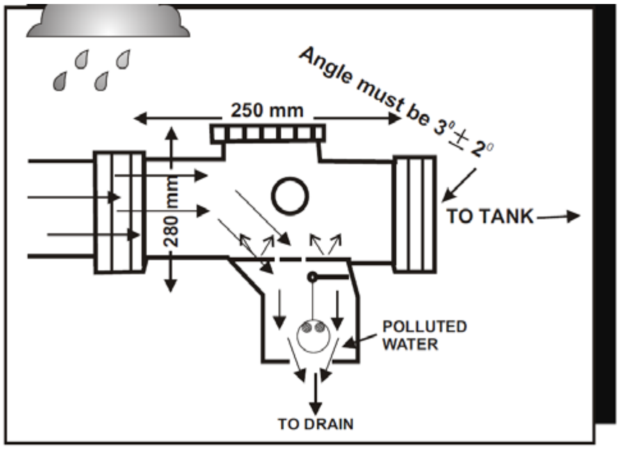
Appendix A: Manufacturer Specifications and Schematics



NBVC Constant Volume First Flush Diverter



Rough Schematic: NBVC 100 Gallon Constant Volume First Flush Diverter



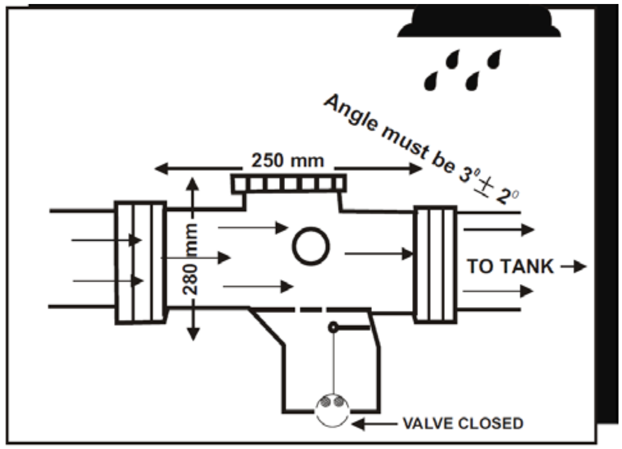
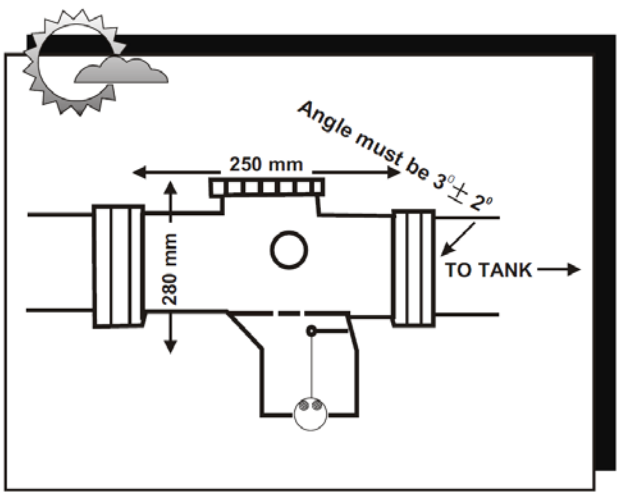


Fig. 1: When rain starts, the stagnant water is dumped from the base of the SafeRain valve.

Fig 2. After the polluted water is dumped, the valve shuts automatically. Clean water is then diverted to the tank.



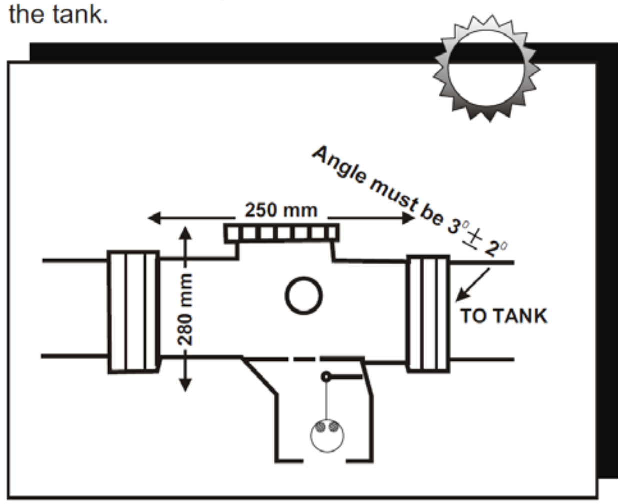


Fig. 3: When the rain stops SafeRain can remain closed for approximately 24 hours. Any further rain during this time goes to the tank.

Fig. 4: SafeRain will drain completely resetting the unit automatically for the next rainfall.

TECHNICAL NOTES

Typically the unit closes at flow rates between 10 litres/min and 20 litres/min adjustable. Any small debris left behind in Fig. 4 is flushed out with the next rain. Large leaves, sticks etc are caught in a detachable screen accessible by the screw access.

The above unit is available in both 90 and 100mm sizes. Once a SafeRain is fitted, polluted water diversion of between 5-1,000 litres is possible depending on setting.

First Flush Diverter Valve Design at NBVC

ET2000e

CONTROLLER

The Calsense ET2000e Irrigation Controller is a powerful, easy-to-use water management controller offering features typically associated with centrally controlled systems – all incorporated into this advanced, stand-alone controller. With the Calsense Water Management System, controllers may be linked together with remote IBM-compatible computers via a variety of communication methods for maximum efficiency and flexibility.

DESCRIPTION

Based upon 32-bit microcontroller technology, the ET2000e provides protection from lateral and mainline breaks, electrical fault and hydraulic limit protection. The unit uses real-time ET and rain information to automatically make daily adjustments to the watering time for each station.

The ET2000e allows irrigation based upon time, ET and/or soil-moisture integrating moisture sensing and ET-based operations. Cycle and soak watering, twelve month programming, and interactive monthly volume budgets are standard with the ET2000e Controller. The ET2000e Controller makes use of the new RRe radio remote for improved remote operation of valves for maintenance purposes.

FEATURES

- Backlit 16-line by 40 character display.
- Multi-level password protection.
- Lifetime program storage without battery backup.
- Central communications options include Hardwire, Local Radio, Ethernet, Wireless Ethernet (WiFi) GPRS radio, Fiber Optic Modem, Spread Spectrum Radio, and Phone.
- English or Spanish menus and help screens.
- UL approved.
- Available in 8, 12, 16, 24, 32, 40 or 48 stations.
- Mainline break protection during irrigation and off-irrigation set points.
- Electrical fault detection and bypass.
- Hydraulic limit setting for maximum irrigation efficiency.
- Detailed water usage reports.
- 10-year warranty.

TECHNICAL SPECIFICATIONS

POWER

Input requirement:	120VAC single phase, 1 amp
Station outputs:	24VAC, 1.5 amps max (short protected)

PHYSICAL

Height:	11.38"	**Color:**	Medium Grey
Depth:	7.25"	**Material:**	16 gauge
Width:	11.13"		Stainless Steel

SHIPPING WEIGHTS

ET2000e, ET2000e-M, ET2000e-R:	19 lbs.
ET2000e-LR, ET2000e-SR, ET2000e-EN, ET2000e-WEN, ET2000e-GR:	21 lbs.

HOW TO SPECIFY MODELS

Number of stations
Controller type
Communications first
Other options

ET2000e-24-LR-G-RB

COMMUNICATIONS OPTIONS

-M	Wire linkable for hardwire or sharing any form of communication with multiple controllers. Each controller in the chain needs option.
-R	Internal phone modem
-LR	Internal local radio modem
-SR	Internal spread spectrum radio
-EN	Internal Ethernet modem
-GR	Internal GPRS modem
- WEN	Internal wireless Ethernet modem
-FOM	Internal fiber optic modem

OTHER OPTIONS

-F	Internal interface for two additional flow meters / master valves.
-G	Internal interface for ET Gage (ETG)
-RB	Internal interface for Tipping Rain Bucket (RB-1)
-WG	Internal interface for Wind Gage (WG-1)
-L	Hardware and software for 4 additional light circuits
-RRe	Calsense enhanced integrated radio remote receiver board
-FL	FlowSense™ software

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Calsense Controller

COMM-1

SOFTWARE

Designed for central control, the Command CENTER Water Management software allows the user to gather and store data from Calsense controllers, print reports and make controller programming changes – all from a single or multiple locations when operating on an IBM compatible PC.

Mapping Feature

Calsense Controllers

DESCRIPTION

Calsense Command CENTER software is an easy-to-use, water management tool. The Windows-based software package is designed to assist the operator in managing irrigation watering. The software features easy, point-and-click mouse control and a user-friendly graphical user interface. The intuitive, menu driven format requires no special training to operate.

Command CENTER software operates only with Calsense controllers. It provides a central point of operation to make programming adjustments, gather and share weather information, gather alerts and generate water savings reports. By sharing real-time weather data, all of the controllers in the system will reapply the right amount of water according to the current day's weather conditions maximizing water savings. The gathering of alerts by the central computer allows the user to pinpoint problem areas, determine the cause and exact location, enabling maintenance crews to handle them quickly and effectively. The Command CENTER Software, when combined with the powerful Calsense controllers, provides a complete system designed to maximize water and labor savings.

Compatible with Local Radio, Spread-Spectrum Radio, Fiber Optic Modem, GPRS, Ethernet, Wireless Ethernet, Phone Modem and Hardwire communication options, the Calsense Command CENTER software gives the user the flexibility to mix and match all options on a single computer (additional serial ports may be necessary). Calsense recommends, although not required, that the central computer be dedicated for irrigation control in order to achieve efficient monitoring of the system.

A new integrated GIS Viewer visually represents a user's controllers on a map using existing GIS (Geographic Information System) data. Highly customizable, this feature shows the status of each controller including mainline breaks and flow alerts through the use of color-coded icons. Additional information about each controller is also available via a built-in legend and by right-clicking controllers on the map

FEATURES

- Easy to use Windows-based menu.
- Includes RRe-TRAN intuitive software to program the enhanced radio remote.
- Requires no special training.
- Graphical user interface.
- Compatible with all Calsense ET model controllers and all communication options.
- Operates up to 9,999 Calsense controllers.

TECHNICAL SPECIFICATIONS

COMPUTER REQUIREMENTS

- IBM PC or 100% compatible, 80586 (Pentium) minimum 1.0 GHz
- Windows Vista/XP/2000
- Minimum 256 MB RAM (512 MB RAM recommended)
- Minimum 150 MB hard disk space (600 MB recommended) for data storage
- CD-ROM drive
- Two serial ports for specific comm options
- 17″ monitor
- 256 color VGA video (True-Color recommended)
- 9600 baud modem (28.8 K or faster non WinModem recommended)
- Microsoft compatible (Mouse & Printer) recommended

MODEL NUMBERS

COMM-1: Calsense Command CENTER Water Management Software

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Calsense Controller Software

CCO command center online

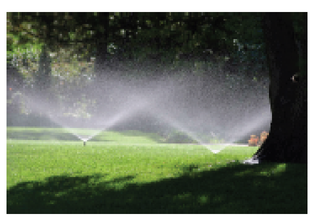
Calsense Command Center Online offers fundamental central control capabilities through a web browser. Each customer's service is unique and password-protected so data is secure. User accounts are issued and managed by an administrator so only authorized users can access controller information.

description

Command Center Online allows customers to create custom dashboards that provide a snapshot of project sites then zero in on specific details. Daily weather information can be shared automatically to adjust station run times to manage water and labor costs. Decisions made and actions taken are based on real-time conditions of the landscape through the reporting capabilities of the software. These include complete records of every irrigation cycle, water usage compared to budget amounts, water savings in both gallons and overall percentage, and events and changes that have happened at the controller.

features

- No software purchase or installation needed
- Users can access their data anywhere, any time, from any internet-connected device
- Software is updated automatically and transparently
- Database is safeguarded through automatic backups



technical specifications

To use Command Center Online:

- One or more ET2000e irrigation controllers with the -GR communication option and/or one or more CS3000 irrigation controllers with the CS3-EN, CS3-WEN, or CS3-GR communication option
- A high-speed internet connection such as DSL, cable or mobile broadband
- A compatible web browser. Supported web browsers include:
  - Microsoft® Internet Explorer® 8 or later
  - Google® Chrome™ 34 or later
  - Mozilla® Firefox® 28 or later
  - Apple® Safari® 5.1.7 or later

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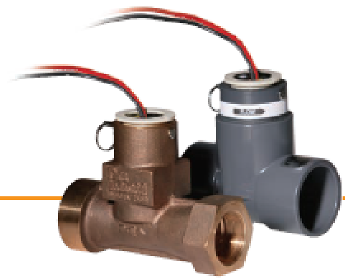
Non Navy Calsense Controller Freeware

FM
SENSORS



Calsense Flow Meters (FM) are used with all Calsense irrigation controllers to monitor real-time flow of potable or non-potable water. The Calsense Flow Meter features a proprietary, non-magnetic sensing mechanism and a six-bladed design. Its unique, forward-swept impeller design provides higher, more constant torque than less efficient four-blade designs, and is less prone to fouling by water-borne debris. The advanced design of the Calsense Flow Meter coupled with an absence of magnetic drag delivers improved operation and consistent repeatability at lower flow rates.

DESCRIPTION

As liquid flow turns the Flow Meter impeller blades, a low impedance 9VDC signal is transmitted with a frequency proportionate to the flow rate. The signal can travel up to 2,000' between the Flow Meter and the Calsense field controller without the need of amplification. Controllers require no additional interface and supply the DC signal directly to the Flow Meter. An optional –F interface may be factory installed to read up to two additional Flow Meters.

FEATURES

- Forward curved impeller.
- Non-magnetic sensing mechanism.
- Unique six-blade design.
- Accuracy +/- 1% of full scale.

RECOMMENDED RANGE

Model	Min Flow (.5 fps)	Recommended Range Min Flow (1 fps)	Recommended Range Max Flow (16 fps)	Max Flow (15 fps)	PSI Loss @ gpm
FM-1B	2 gpm	3 gpm	50 gpm	50 gpm	0.5 psi @ 36 gpm
FM-1.25B	3 gpm	5 gpm	81 gpm	81 gpm	0.5 psi @ 69 gpm
FM-1.5B	4 gpm	7 gpm	105 gpm	106 gpm	0.5 psi @ 96 gpm
Model	**Min Flow (.5 fps)**	**Recommended Range Min Flow (1 fps)**	**Recommended Range Max Flow (16 fps)**	**Max Flow (30 fps)**	**PSI Loss @ gpm**
FM-1.5	4 gpm	7 gpm	105 gpm	212 gpm	0.5 psi @ 96 gpm
FM-2	6 gpm	11 gpm	166 gpm	333 gpm	0.5 psi @ 165 gpm
FM-2B	6 gpm	11 gpm	166 gpm	333 gpm	0.5 psi @ 165 gpm
FM-3	12 gpm	24 gpm	363 gpm	727 gpm	0.5 psi @ 390 gpm
Model	**Min Flow (.5 fps)**	**Recommended Range Min Flow (1 fps)**	**Recommended Range Max Flow (16 fps)**	**Max Flow (30 fps)**	**PSI Loss @ gpm**
FMBX	.5 fps	1 fps	15 fps	30 fps	N/A

TECHNICAL SPECIFICATIONS

PARAMETERS: FM-1B, FM-1.25B, FM-1.5B

Accuracy: +/- 1% of full scale
Linearity: +/- 0.7%
Repeatability: +/- 0.7%
Flow Range: 0.5 to 15 feet/second
Max. Pressure: 400 psi@150°F (65.5°C)

PARAMETERS: FM-2B

Accuracy: +/- 1% of full scale
Linearity: +/- 1%
Repeatability: +/- 1%
Flow Range: 1 to 30 feet/second
Max. Pressure: 200 psi@150°F (65.5°C)

PARAMETERS: FM-1.5, FM-2, FM-3

Accuracy: +/- 1% of full scale
Linearity: +/- 0.5%
Repeatability: +/- 0.5%
Flow Range: 1 to 30 feet/second
Max. Pressure: 100 psi@68°F (20°C)

INSERT CONSTRUCTION

Impeller: Glass reinforced nylon
Bearing: Ultrahigh molecular weight polyethelene
Shaft: Tungsten Carbide
Housing: Glass reinforced polyphenylene sulfide
O-rings: Ethylene propylene

BODY CONSTRUCTION

FM-B series: Bronze
FM series: Schedule 80 PVC

SIZING CHART

(See Calsense Designers Guide for more details)

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Calsense Flow Sensor

1000-S
SENSOR

The Calsense Model 1000-S moisture sensor provides the user with improved water savings by letting the system respond to actual soil moisture. The Model 1000-S moisture sensor is designed to send soil moisture readings directly to the Calsense ET2000 and ET2000e irrigation controller. The Calsense irrigation controller will automatically stop irrigation when the proper soil moisture level has been reached.

DESCRIPTION

A solid-state tensiometer type moisture sensor, Calsense Model 1000-S moisture sensor operates with the Calsense Model ET2000 and ET2000e irrigation controllers. The Calsense 1000-S moisture sensor provides consistant long-term soil moisture readings to the Calsense irrigation controller. The moisture sensor electronics are encased in a protective durable epoxy, increasing the life expectancy of the product. The Model 1000-S moisture sensor readings are unaffected by temperature, salinity or changes in soil pH.

The moisture data is transmitted to the irrigation controller on the remote control valve wiring. Special wires that run between the irrigation controller and the sensor are not necessary. The only additional wiring required is between the remote control valve and the Model 1000-S sensor, using 14AWG wire. The total maximum wire run between moisture sensor and the irrigation controller is 3,000 feet. There is no maintenance or calibration required for the life of the sensor.

The Calsense Models ET2000 and ET2000e irrigation controllers, using the sensor to measure available water in the pore space of the soil, makes a decision before each cycle start whether or not to continue applying water. This decision is based on the actual moisture reading compared to the user-determined moisture set point. A representative station for each different climatic and plant material zone is given a sensor and is known as a Master Station. Slave Stations are stations without sensors and are assigned to a master station that shares similar water requirements. The user chooses groups of stations controlled by the same sensor during initial setup. Stations can be easily changed or moved from one sensor to another through user-friendly controller programming. A general guideline of one moisture sensor per four active valves works well to cover varying site conditions.

Proper placement of the moisture sensor is important. Calsense will provide technical support at no-charge to assist in the proper location of the moisture sensor for the most efficient system.

FEATURES

- Requires no special wiring.
- No calibration for the life of the sensor.
- 5-year warranty

TECHNICAL SPECIFICATIONS

CONSTRUCTION

Epoxy encapsulated electronics

Sensor Dimensions: 6.4"L x 1.9"W x 1.6"H

MODEL NUMBER

1000-S: Moisture Sensor

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Calsense Moisture Sensor

ETG
SENSOR

Calsense provides a simple yet powerful tool to monitor daily evapotranspiration with the Calsense ET Gage. Used with the ET2000 and ET2000e irrigation controllers, the ET Gage measures daily evapotranspiration, and is used to automatically calculate station run times so the irrigation system can apply the exact amount of water required for current weather conditions.

DESCRIPTION

The ET Gage is designed to evaporate water at the same rate as tall fescue. The ET Gage sends daily measurements to the irrigation controller. The controller maintains a 28-day table of ET measurements. Daily ET measurements are typically .10″ to .30″ for a 24-hour period. When it comes time to irrigate a station, the sum of ET numbers since the last irrigation are used to automatically calculate run times.

Designed with a hardwearing, ceramic evaporation plate and weatherproof PVC plastic housing, the Calsense ET Gage delivers +/- 1% accuracy of evaporated water. The ET Gage requires minimal maintenance – filling with distilled water approximately every 2 months and cleaning the top surface and water reservoir twice a year. The gage is powered directly by the Calsense controller, thus eliminating the use of batteries.

PLACEMENT

Proper location of the ET Gage is important. It should be mounted in a location that meets the following requirements:

- Location representative of the area to be irrigated.
- Area not obstructed from wind or sunlight.
- Water from irrigation system does not hit the top surface of the ET Gage.
- Multiple controllers can share one ET Gage when -M multi communication boards are specified.

OPTION

The ET2000 or ET2000e irrigation controller requires the –G interface for connecting to the ET Gage. Available with Vandal Resistant Stainless Steel Enclosure, model ETGE.

FEATURES

- Hard-wearing, ceramic evaporation plate.
- Weatherproof PVC plastic housing.
- +/- 1% accuracy of evaporated water.
- Resolution .01″.
- Temperature limits above freezing to 158°F.
- Humidity 0% to 100% RH.

TECHNICAL SPECIFICATIONS

DIMENSIONS

Height: 22.3″
Diameter: 3.1″
Weight: 5.5 lbs. (with water)
3.1 lbs. (empty)
Mounting: Stainless steel vertical bracket

MODEL NUMBERS

ETG: ET Gage
ETGE: Vandal Resistant Stainless Steel Enclosure

VANDAL RESISTANT ENCLOSURE

The Calsense ET Gage vandal resistant enclosure is used primarily as a cover for the ET Gage. This helps to prevent damage to the Gage from tampering, vandalism, or animal interference.

- The enclosure base post is made from 16 gage electro-galvanized 304 stainless steel.
- The body assembly is manufactured from 5 inch diameter 304 stainless steel tubing.
- The mesh screen is 16 gage 1/4 inch stainless steel.
- The two (2) T-handle assemblies are manufactured from 5/8 inch round 304 stainless steel.

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Calsense ET Gauge

RB-1
SENSOR

The Calsense RB-1 Tipping Rain Bucket offers an accurate and simple way to measure rainfall when used with the ET2000 or ET2000e irrigation controller. Rainfall measurements are used to offset evapotranspiration (ET) losses and save users water and time by automatically adjusting station run times.

DESCRIPTION

The Tipping Rain Bucket features a gold anodized aluminum collection funnel with a knife-edge that diverts the water to a tipping bucket mechanism. A momentary switch closer takes place with each tip of the bucket and is monitored in real-time by a Calsense ET2000 or ET2000e controller. The RB-1 can be connected to more than one controller on a given site or share data with other controllers via Calsense Command CENTER software installed on a personal computer using one of the many communication options available.

Each RB-1 features an aluminum sensor housing covered with a durable, baked enamel surface that will withstand years of exposure to the environment. Factory calibrated, the sensor should never need calibration. The Calsense Rain Bucket offers convenient mounting options and hardware including three sensor support legs for surface mounting, side bracket and clamps for pole mounting, and a 60-foot long, two-conductor sensor cable. Mounting surface must be vibration free and allow for level installation of sensor.

OPTION

Tipping Rain Bucket is read by the optional factory-installed -RB interface board. The ET2000 or ET2000e irrigation controllers require the -RB interface for connecting to the Tipping Rain Bucket.

FEATURES

- Accuracy of 1% at 2 inches/hr. or less.
- Resolution: 0.01 inches.
- Average switch closure time 135ms.
- Maximum switch rating 30 VDC @ 2 A, 115 VAC @ 1 A.
- Maximum bounce settling time .75ms.
- Maximum bounce closure time .25ms.
- Temperature limits 32°F to 125°F.
- Calibration of 16 fluid oz./100 bucket tips.

TECHNICAL SPECIFICATIONS

DIMENSIONS

Height:	9.5″ (less mounting legs)
Diameter:	6.25″(less mounting bracket)
Weight:	2.5 lbs.
Body:	Aluminum with white baked enamel
Receiving Orifice:	Gold anodized aluminum
Mountings:	Flat surface or pole

MODEL NUMBER

RB-1: Calsense Tipping Rain Bucket

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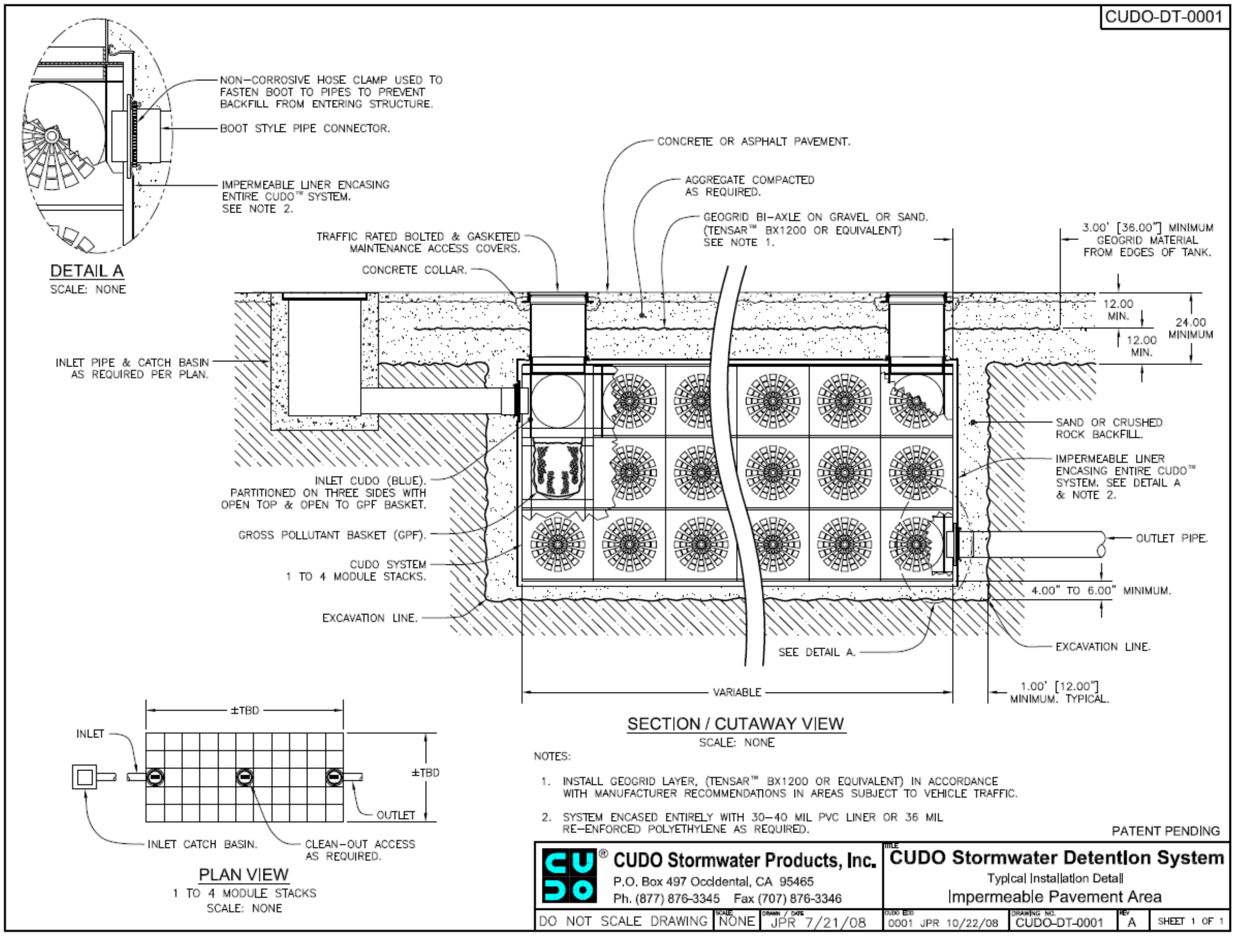
Calsense Rain Bucket



CUDO Harvest Tank General Design

PUMP PERFORMANCE

PULSAR DRY
SUBMERSIBLE PUMPS

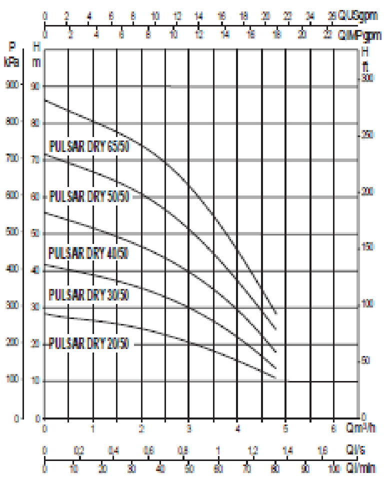
Available from:

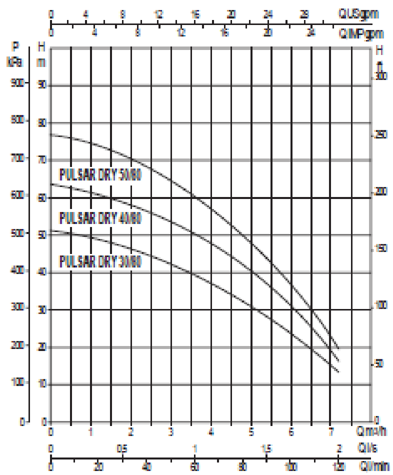
RainHarvest Systems
www.RainHarvest.com

CE

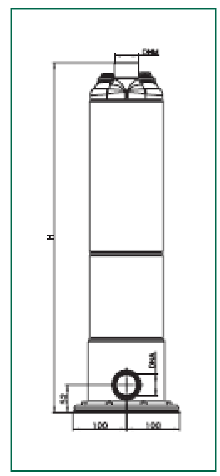
The PULSAR DRY pumps are used in lifting and pressurisation systems for water from primary collection tanks or wells and are suitable for providing pressurised water in domestic systems, small-scale farming and sprinkler systems for gardens and vegetable gardens. The pump is extremely silent and this feature makes it suitable for use with pressurisation systems in unventilated rooms or in areas prone to flooding. Single-piece multi-stage bore-hole pump or of surface with hydraulic assembly positioned under the motor which is cooled by the pumped liquid. Impellers, diffusers, filter and oil sump in abrasion-proof thermoplastic. Pumpliner, stator sleeve, upper head with sleeve and sealing ring in AISI 304 steel. Upper and lower bearing supports in dezincification-proof pressed brass. Rotor shaft extension in AISI 304. Elastomers in NBR. Stainless steel hardware. Double mechanical seal separated by an oil chamber, in ceramic/carbon on the motor side and carburundum/carburundum on the pump side. The sealing system ensures the motor remains airtight and the mechanical seal holds even after brief periods of no-water operation.
Continuous service asynchronous submersible motor. Stator incorporated in an AISI 304 stainless steel airtight casing with a cover housing the cables and capacitor. Rotor mounted on oversized ball bearings to ensure silent running and long life. Incorporated thermal current protection and permanently connected capacitor in the single-phase version. As regards three-phase protection, a motor overload cut out should be fitted, in accordance with current standards. Built to IEC 2-3 and IEC 61-69 (EN 60335-2-41).
Operating range:from 0.9 to 7.2 m^3/h with a head of up to 86 m
Max. quantity of sand in water: 50 gr/m^3
Protection level of motor:IP 68
Protection class of motor:F
Liquid temperature range:da 0°C a +40°C
Maximum depth of immersion:20 metres
Standard cables: 15 m of HO7 RNF cable complete with SCHUKO EEC 7-VII-UNEL 47166-68 plug for the single-phase version. The single-phase versions can be supplied with or without floats for automatic operation.

HYDRAULIC DATA





DIMENSIONS AND WEIGHTS



MODEL	ELECTRICAL DATA							HYDRAULIC DATA								DIMENSIONS AND WEIGHTS							
	VOLTAGE 50 Hz	P1 kW	P2		In A	CAPACITOR		Q m^3/h	0	1,2	2,4	3,6	4,8	6	7,2	H	PACKAGING DIMENSIONS			VOLUME m^3	WEIGHT Kg		
			kW	HP		µF	Vc	l/min	0	20	40	60	80	100	120		L/A	L/B	H		MA	MNA	TNA
PULSAR DRY 20/50 M-NA	1 x 220-240 V~	0,78	0,55	0,75	3,7	20	450	H (m)	29	27	23,2	17,2	10,3			603	780	240	265	0,049	-	16,5	17
PULSAR DRY 20/50 T-NA	3 x 400 V~	0,60	0,55	0,75	1,62	-	-																
PULSAR DRY 30/50 M-NA	1 x 220-240 V~	0,94	0,55	0,75	4,4	16	450		42	38,2	33,8	24,8	13,5			562	690	220	165	0,049	-	16,7	17,3
PULSAR DRY 30/50 T-NA	3 x 400 V~	0,87	0,55	0,75	1,65	-	-																
PULSAR DRY 40/50 M-NA	1 x 220-240 V~	1,12	0,75	1	5,2	16	450		56	51	45	33	18			562	690	220	165	0,049	-	17	17,5
PULSAR DRY 40/50 T-NA	3 x 400 V~	1,03	0,75	1	1,85	-	-																
PULSAR DRY 50/50 M-NA	1 x 220-240 V~	1,45	1	1,36	6,5	25	450		72	65,5	58	43,6	24,5			630	690	220	165	0,049	-	18	18,5
PULSAR DRY 50/50 T-NA	3 x 400 V~	1,35	1	1,36	2,4	-	-																
PULSAR DRY 65/50 M-NA	1 x 220-240 V~	1,70	1,2	1,6	7,8	30	450		86	78,5	70	52,8	29			657	690	220	165	0,049	-	19	19,5
PULSAR DRY 65/50 T-NA	3 x 400 V~	1,60	1,2	1,6	2,9	-	-																
PULSAR DRY 30/80 M-NA	1 x 220-240 V~	1,12	0,75	1	5,2	16	450		51	48,2	44,8	39,2	32,4	23,5	13	562	690	220	165	0,049	-	17	17,5
PULSAR DRY 30/80 T-NA	3 x 400 V~	1,03	0,75	1	1,85	-	-																
PULSAR DRY 40/80 M-NA	1 x 220-240 V~	1,45	1	1,36	6,5	25	450		64	61	56,8	50	41,5	30,5	16,2	630	690	220	165	0,049	-	18	18,5
PULSAR DRY 40/80 T-NA	3 x 400 V~	1,35	1	1,36	2,4	-	-																
PULSAR DRY 50/80 M-NA	1 x 220-240 V~	1,70	1,2	1,6	7,8	30	450		77	73,2	68	60	50	37	19,6	657	690	220	165	0,049	-	19	19,5
PULSAR DRY 50/80 T-NA	3 x 400 V~	1,60	1,2	1,6	2,9	-	-																

Harvest Tank Submersible Pump

TECHNICAL DATA

APPLICATION

APPLICATION

DESCRIPTION

SMART PRESS is an ON/OFF electronic system designed to regulate the pump work, without using an expansion vessel.

The device stops the pump to protect against dry running without using level probes or float switch.

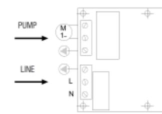
It has an adjustable cut-in pressure and even with a high flow the pressure losses are small.

The WG (WATER GUARDIAN) version of the SMART PRESS will try to restart the pump every 30 miutes after the dry run protection has stopped the pump.

All the SMART PRESS models have a MANUAL RESTART.
The standard version is not supplied with cables

TECHNICAL DATA

ELECTRICAL CONNECTIONS



TECHNICAL DATA

TECHNICAL DATA

FEATURES & BENEFITS

- Plug and Play
- No Pressure Tank Required
- Compact Design
- Weather Proof (Always recommended to protect from the elements)
- 2 Pressure versions available (25psi & 40psi)
- Dry Run Protection
- Automatic Operation
- Available in 1 Phase 115v & 230v 60Hz
- Adjustable Start Pressure
- WG Version with auto-restart

TECHNICAL DATA

OPERATION

1) Controls pump operation, automatically and without interruption, with constant pressure and delivery during supply from one or more distribution points. The pump starts when the pressure of the system is less than the fixed pressure (std 1.5 bar). Il stops when Smart Press no longer detects an appreciable outlet flow (see point 2).

2) Keeps the pump operating for a brief period (approximately 5 seconds) after supply has stopped at the tap closing.

3) If there is no water at the suction point, it blocks the pump,without using level probes or float switches.Or it releases automatically when a pressure above the one required to start the motor-driven pump is injected in the delivery line.

One version of system is identified as Smart Press WG (where WG is for Water Guardian). In case of block due to lack of water, this system effects some tries of automatic random, as equal as pressing the pushbutton of manual reset, every 30 Min.

4) It is supplied with a flow sensor, manufactured with a geometry which reduces the loading losses even with very high flows.

5) Lights indicate the various operation phases:
green LED on: present power supply
yellow LED on: pump working
red LED on: blocked due to lack of water at supply point.

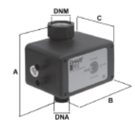
MODEL DATA

Model	Item code	Max Motor current amps	Max Motor Power HP	Power Supply Volt	Set Pressure psi	Settable Range psi
SMART PRESS 1.5HP WG	88001976	20	1.5	1~ 115v 50/60Hz	25	20 - 30
SMART PRESS 3.0HP WG	88001979	20	3.0	1~ 230v 50/60Hz	25	20 - 30
SMART PRESS 1.5 HP WG 2.8	60143793	20	1.5	1~ 115v 50/60Hz	40	35 - 45
SMART PRESS 3.0 HP WG 2.8	60143792	20	3.0	1~ 230v 50/60Hz	40	35 - 45

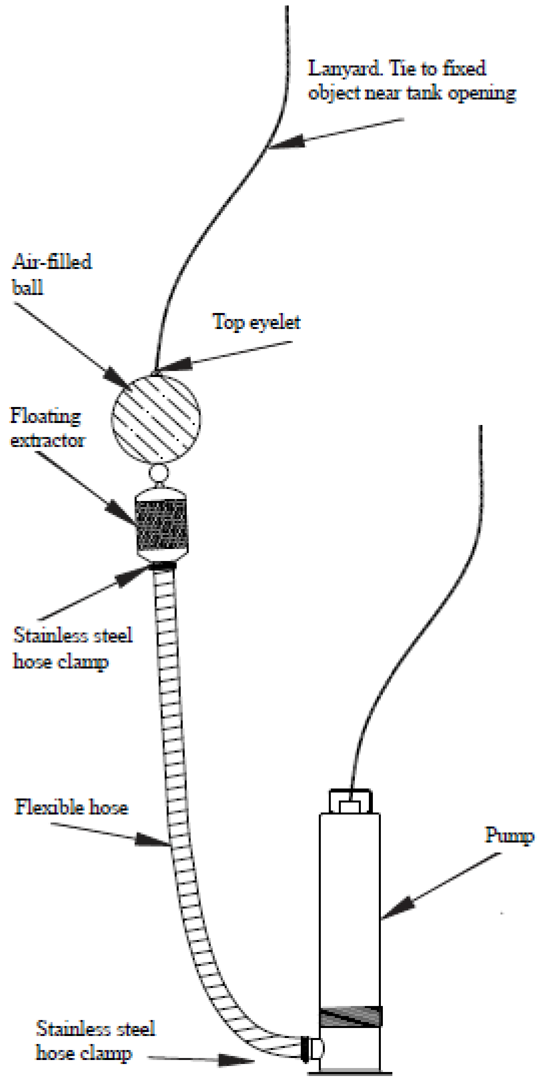
DIMENSIONS

SMART PRESS Dimensions (Inches)

MODEL	DNA	DNM	A	B	C
SMART PRESS 1.5 HP WG	1"	1" 1/4	8	9	6
SMART PRESS 3.0 HP WG	1"	1" 1/4	8	9	6
SMART PRESS 1.5 HP WG 2.8	1"	1" 1/4	8	9	6
SMART PRESS 3.0 HP WG 2.8	1"	1" 1/4	8	9	6



Harvest Tank Submersible Pump Regulator



Maintenance

Quarterly:

Using the lanyard, raise and inspect the filter mesh openings and mounting hardware. Clean with non-toxic citrus cleaner and a brush if necessary.

Annually (spring re-commissioning):

Inspect the entire assembly for sediment buildup, corrosion, abrasion and verify that the hose clamps are secure. Clean or repair any deficiencies before re-commissioning your system.

Stainless Steel Floating Filter with 1.25" Coarse Screen

Harvest Tank Submersible Pump Filter

RAIN BIRD

TECH SPECS

Matched Precipitation Rate (MPR) Nozzles

Primary Application

Matched Precipitation Rate (MPR) Nozzles simplify the design process by allowing sprinklers with various arcs and radii to be mixed on the same circuit. Fits all Rain Bird spray heads and shrub adapters.

Features

- Matched precipitation rates across sets and across patterns in new 5 Series, 8 Series, 10 Series, 12 Series and 15 Series for even water distribution and design flexibility.
- New 5 Series nozzles meet small-area shrub or turf requirements.
- New and improved 8 Series Nozzles now have a lower water flow which allow more spray heads per zone.
- 1800 Series white filter (0.35" x 0.45") screens (shipped with nozzles) maintain precise radius adjustment and prevent clogging. New and improved 5 and 8 Series Nozzles are shipped with blue fine-mesh (0.02" x 0.02") filter screens.
- Stainless steel adjustment screw to adjust flow and radius.
- Color-coded on the top to enhance your productivity.

Operating Range

- **Spacing:** 5 to 15 feet (1,5 to 4,5 m)
- **Pressure:** 15 to 30 psi (1 to 2,1 Bars)
- **Optimum Pressure:** 30 psi (2,1 Bars)

Specifications

5, 8, 10, 12 and 15 Series MPR Nozzles:

The nozzles shall have precipitation rates matched across sets and across patterns.

The plastic MPR Nozzle shall be constructed of UV-resistant plastic. The radius adjustment screen shall be constructed of stainless steel.

The nozzle shall accept the non-clogging 1800 Series filter screens to allow for radius adjustment and the MPR Plastic Nozzles shall also accept the pressure compensating screens (PCS Series).

The Plastic MPR Nozzles shall be manufactured by Rain Bird Corporation, Azusa, California.

Models

- 5 Series – red
- 5 Series, Bubbler Nozzles – gray
- 8 Series – green
- 10 Series – blue
- 12 Series – brown
- 15 Series – black
- 15 Strip Series – black

5 SERIES MPR

5° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm	■ Precip In/h	▲ Precip In/h
5F	15	2	0.09	2.07	2.39
	20	3	0.19	2.01	2.32
	25	4	0.27	1.62	1.87
	30	5	0.41	1.58	1.83
5H	15	2	0.04	2.07	2.39
	20	3	0.09	2.01	2.32
	25	4	0.13	1.62	1.87
	30	5	0.20	1.58	1.83
5Q	15	2	0.02	2.07	2.39
	20	3	0.05	2.01	2.32
	25	4	0.07	1.62	1.87
	30	5	0.10	1.58	1.83

Metric
5° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/h	■ Precip mm/h	▲ Precip mm/h
5F	1,0	0,6	0,02	52	60
	1,5	1,0	0,05	47	55
	2,0	1,4	0,08	41	48
	2,1	1,5	0,09	40	46
5H	1,0	0.6	0,01	52	60
	1,5	1,0	0,02	47	55
	2,0	1,4	0,04	41	48
	2,1	1,5	0,05	40	46
5Q	1,0	0,6	0,01	52	60
	1,5	1,0	0,01	47	55
	2,0	1,4	0,02	41	48
	2,1	1,5	0,02	40	46

NOTE: All MPR Nozzles tested on 4" (10,2 cm) pop-ups.

■ Square spacing based on 50% diameter of throw. ▲ Triangular spacing based on 50% diameter of throw.

Performance data taken in zero wind conditions.

NOTE: Specify sprinkler body and nozzles separately. Refer to Price List for shipping quantities.

NOTE: Radius reduction over 25% of the normal throw of the nozzle is not recommended.

Performance data derived from tests that conform with ASAE Standards; ASAE S398.1.

How To Specify/Order:

1804 - SAM - 15H - PCS - 060

- 1804: Model
- SAM: Optional Feature
- 15H: Nozzle Series Pattern
- PCS - 060: Optional Performance Screen

This specifies an 1800 Series Sprayhead with 4" (10 cm) pop-up height; Seal-A-Matic™ check valve; 15 Series Nozzle providing 180° coverage and pressure-compensating screen to reduce radius to 5' (1,5 m) at 30 psi (2,1 bars) and bring flow down to 0.6 GPM (0,14 m³/h; 0,04 l/s).

■ Square spacing based on 50% diameter of throw.
▲ Triangular spacing based on 50% diameter of throw.

NOTE: Specify sprinkler body and nozzles separately. Refer to Price List for shipping quantities.

NOTE: Radius reduction over 25% of the normal throw of the nozzle is not recommended.

RainBird Nozzles

8 SERIES MPR

10° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm	■ Precip In/h	▲ Precip In/h
8F	15	5	0.54	2.07	2.39
	20	6	0.75	2.01	2.32
	25	7	0.82	1.62	1.87
	30	8	1.05	1.58	1.83
8H	15	5	0.27	2.07	2.39
	20	6	0.38	2.01	2.32
	25	7	0.41	1.62	1.87
	30	8	0.52	1.58	1.83
8T	15	5	0.18	2.07	2.39
	20	6	0.25	2.01	2.32
	25	7	0.27	1.62	1.87
	30	8	0.35	1.58	1.83
8Q	15	5	0.13	2.07	2.39
	20	6	0.19	2.01	2.32
	25	7	0.21	1.62	1.87
	30	8	0.26	1.58	1.83

Metric
10° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/hr	Flow l/s	■ Precip mm/h	▲ Precip mm/h
8F	1,0	1,5	0,12	0,03	52	60
	1,5	1,9	0,16	0,05	47	55
	2,0	2,3	0,22	0,06	41	48
	2,1	2,4	0,23	0,06	40	46
8H	1,0	1,5	0,06	0,02	52	60
	1,5	1,9	0,09	0,02	47	55
	2,0	2,3	0,11	0,03	41	48
	2,1	2,4	0,12	0,03	40	46
8T	1,0	1,5	0,04	0,01	52	60
	1,5	1,9	0,06	0,02	47	55
	2,0	2,3	0,07	0,02	41	48
	2,1	2,4	0,08	0,02	40	46
8Q	1,0	1,5	0,03	0,01	52	60
	1,5	1,9	0,04	0,01	47	55
	2,0	2,3	0,05	0,02	41	48
	2,1	2,4	0,06	0,02	40	46

10 SERIES MPR

15° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm	■ Precip In/h	▲ Precip In/h
10F	15	7	1.16	2.28	2.63
	20	8	1.30	1.96	2.26
	25	9	1.44	1.71	1.98
	30	10	1.58	1.52	1.75
10H	15	7	0.58	2.28	2.63
	20	8	0.65	1.96	2.26
	25	9	0.72	1.71	1.98
	30	10	0.79	1.52	1.75
10T	15	7	0.39	2.28	2.63
	20	8	0.43	1.96	2.26
	25	9	0.48	1.71	1.98
	30	10	0.53	1.52	1.75
10Q	15	7	0.29	2.28	2.63
	20	8	0.33	1.96	2.26
	25	9	0.36	1.71	1.98
	30	10	0.39	1.52	1.75

Metric
15° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/hr	Flow l/s	■ Precip mm/h	▲ Precip mm/h
10F	1,0	2,1	0,26	0,07	58	67
	1,5	2,4	0,29	0,08	50	58
	2,0	3,0	0,35	0,10	39	45
	2,1	3,1	0,36	0,10	37	43
10H	1,0	2,1	0,13	0,04	58	67
	1,5	2,4	0,14	0,04	50	58
	2,0	3,0	0,18	0,05	39	45
	2,1	3,1	0,18	0,05	37	43
10T	1,0	2,1	0,09	0,03	58	67
	1,5	2,4	0,10	0,03	50	58
	2,0	3,0	0,12	0,03	39	45
	2,1	3,1	0,12	0,03	37	43
10Q	1,0	2,1	0,06	0,02	58	67
	1,5	2,4	0,07	0,02	50	58
	2,0	3,0	0,09	0,03	39	45
	2,1	3,1	0,09	0,03	37	43

12 SERIES MPR

30° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm	■ Precip In/h	▲ Precip In/h
12F	15	9	1.80	2.14	2.47
	20	10	2.10	2.02	2.34
	25	11	2.40	1.91	2.21
	30	12	2.60	1.74	2.01
12TQ	15	9	1.35	2.14	2.47
	20	10	1.58	2.02	2.34
	25	11	1.80	1.91	2.21
	30	12	1.95	1.74	2.01
12H	15	9	0.90	2.14	2.47
	20	10	1.05	2.02	2.34
	25	11	1.20	1.91	2.21
	30	12	1.30	1.74	2.01
12T	15	9	0.60	2.14	2.47
	20	10	0.70	2.02	2.34
	25	11	0.80	1.91	2.21
	30	12	0.87	1.74	2.01
12Q	15	9	0.45	2.14	2.47
	20	10	0.53	2.02	2.34
	25	11	0.60	1.91	2.21
	30	12	0.65	1.74	2.01

Metric
30° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/hr	Flow l/s	■ Precip mm/h	▲ Precip mm/h
12F	1,0	2,7	0,40	0,11	55	63
	1,5	3,2	0,48	0,14	47	54
	2,0	3,6	0,59	0,16	46	53
	2,1	3,7	0,60	0,16	44	51
12TQ	1,0	2,7	0,30	0,09	55	63
	1,5	3,2	0,36	0,10	47	54
	2,0	3,6	0,45	0,12	46	53
	2,1	3,7	0,45	0,12	44	51
12H	1,0	2,7	0,20	0,06	55	63
	1,5	3,2	0,24	0,07	47	54
	2,0	3,6	0,30	0,08	46	53
	2,1	3,7	0,30	0,08	44	51
12T	1,0	2,7	0,13	0,04	55	63
	1,5	3,2	0,16	0,05	47	54
	2,0	3,6	0,20	0,05	46	53
	2,1	3,7	0,20	0,05	44	51
12Q	1,0	2,7	0,10	0,03	55	63
	1,5	3,2	0,12	0,03	47	54
	2,0	3,6	0,15	0,04	46	53
	2,1	3,7	0,15	0,04	44	51

15 SERIES MPR

30° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm	■ Precip In/h	▲ Precip In/h
15F	15	11	2.60	2.07	2.39
	20	12	3.00	2.01	2.32
	25	14	3.30	1.62	1.87
	30	15	3.70	1.58	1.83
15TQ	15	11	1.95	2.07	2.39
	20	12	2.25	2.01	2.32
	25	14	2.48	1.62	1.87
	30	15	2.78	1.58	1.83
15H	15	11	1.30	2.07	2.39
	20	12	1.50	2.01	2.32
	25	14	1.65	1.62	1.87
	30	15	1.85	1.58	1.83
15T	15	11	0.87	2.07	2.39
	20	12	1.00	2.01	2.32
	25	14	1.10	1.62	1.87
	30	15	1.23	1.58	1.83
15Q	15	11	0.65	2.07	2.39
	20	12	0.75	2.01	2.32
	25	14	0.82	1.62	1.87
	30	15	0.92	1.58	1.83

Metric
30° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/hr	Flow l/s	■ Precip mm/h	▲ Precip mm/h
15F	1,0	3,4	0,60	0,16	52	60
	1,5	3,9	0,72	0,19	47	55
	2,0	4,5	0,84	0,23	41	48
	2,1	4,6	0,84	0,23	40	46
15TQ	1,0	3,4	0,45	0,12	52	60
	1,5	3,9	0,54	0,15	47	55
	2,0	4,5	0,63	0,17	41	48
	2,1	4,6	0,63	0,18	40	46
15H	1,0	3,4	0,30	0,08	52	60
	1,5	3,9	0,36	0,10	47	55
	2,0	4,5	0,42	0,11	41	48
	2,1	4,6	0,42	0,12	40	46
15T	1,0	3,4	0,20	0,05	52	60
	1,5	3,9	0,24	0,07	47	55
	2,0	4,5	0,28	0,08	41	48
	2,1	4,6	0,28	0,08	40	46
15Q	1,0	3,4	0,15	0,04	52	60
	1,5	3,9	0,18	0,05	47	55
	2,0	4,5	0,21	0,06	41	48
	2,1	4,6	0,21	0,06	40	46

NOTE: All MPR Nozzles tested on 4" (10,2cm) pop-ups.
■ Square spacing based on 50% diameter of throw. ▲ Triangular spacing based on 50% diameter of throw.
Performance data taken in zero wind conditions.
NOTE: Specify sprinkler body and nozzles separately. Refer to Price List for shipping quantities.
NOTE: Radius reduction over 25% of the normal throw of the nozzle is not recommended.
Performance data derived from tests that conform with ASAE Standards; ASAE S398.1.

RainBird Nozzles Continued

15 STRIP SERIES

30° Trajectory

Nozzle	Pressure psi	W x L ft	Flow gpm
15SQ	15	18 x 18	2.68
	20	19 x 19	3.06
	25	21 x 21	3.42
	30	23 x 23	3.73
15EST	15	4 x 13	0.45
	20	4 x 14	0.50
	25	4 x 14	0.56
	30	4 x 15	0.61
15CST	15	4 x 26	0.89
	20	4 x 28	1.00
	25	4 x 28	1.11
	30	4 x 30	1.21
15SST	15	4 x 26	0.89
	20	4 x 28	1.00
	25	4 x 28	1.11
	30	4 x 30	1.21
9SST	15	9 x 15	1.34
	20	9 x 16	1.47
	25	9 x 18	1.60
	30	9 x 18	1.73

Metric
30° Trajectory

Nozzle	Pressure bar	W x L m	Flow m³/h	Flow l/s
15SQ	1,0	5,5 x 5,5	0,61	0,17
	1,5	5,8 x 5,8	0,69	0,19
	2,0	6,4 x 6,4	0,78	0,22
	2,1	7,0 x 7,0	0,85	0,23
15EST	1,0	1,2 x 4,0	0,10	0,03
	1,5	1,2 x 4,3	0,11	0,03
	2,0	1,2 x 4,3	0,13	0,04
	2,1	1,2 x 4,6	0,14	0,04
15CST	1,0	1,2 x 7,9	0,20	0,06
	1,5	1,2 x 8,5	0,23	0,06
	2,0	1,2 x 8,5	0,25	0,07
	2,1	1,2 x 9,2	0,27	0,08
15SST	1,0	1,2 x 7,9	0,20	0,06
	1,5	1,2 x 8,5	0,23	0,06
	2,0	1,2 x 8,5	0,25	0,07
	2,1	1,2 x 9,2	0,27	0,08
9SST	1,0	2,7 x 4,6	0,30	0,08
	1,5	2,7 x 4,9	0,33	0,09
	2,0	2,7 x 5,5	0,36	0,10
	2,1	2,7 x 5,5	0,39	0,11

W = Width of coverage pattern L = Length of coverage pattern

5 SERIES MPR STREAM BUBBLER NOZZLES

0° Trajectory

Nozzle	Pressure psi	Radius ft	Flow gpm
5F-B	15	5	1.50
	20	5	1.50
	25	5	1.50
	30	5	1.50
5H-B	15	5	1.00
	20	5	1.00
	25	5	1.00
	30	5	1.00
5Q-B	15	5	0.50
	20	5	0.50
	25	5	0.50
	30	5	0.50
5CST-B	15	5	0.50
	20	5	0.50
	25	5	0.50
	30	5	0.50

Metric
0° Trajectory

Nozzle	Pressure bar	Radius m	Flow m³/h	Flow l/s
5F-B	1,0	1,5	0,35	0,09
	1,5	1,5	0,35	0,09
	2,0	1,5	0,35	0,09
	2,1	1,5	0,35	0,09
5H-B	1,0	1,5	0,23	0,06
	1,5	1,5	0,23	0,06
	2,0	1,5	0,23	0,06
	2,1	1,5	0,23	0,06
5Q-B	1,0	1,5	0,12	0,03
	1,5	1,5	0,12	0,03
	2,0	1,5	0,12	0,03
	2,1	1,5	0,12	0,03
5CST-B	1,0	1,5	0,12	0,03
	1,5	1,5	0,12	0,03
	2,0	1,5	0,12	0,03
	2,1	1,5	0,12	0,03

NOTE: Indicates adjusted radius at psi shown. Flow at adjusted radius of 5 feet (1,5 m).

RainBird Nozzles Continued

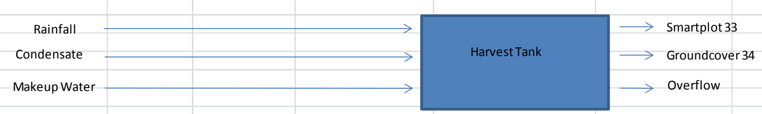
Valve Size	1.5 in
Valve Type	Inline
Material	Plastic
Valve Inlet/Outlet Configuration	NPT Female x NPT Female Threaded
Valve Options	Dirty Water
Valve Series	PESB-R
Operating Temperature	Up to 150° F (66° C)
Electrical Specifications	24 VAC 50/60 Hz (cycles per second) solenoid Inrush current: 0.41A (9.9VA) Holding current: 0.14A (3.43VA) Coil resistance: 30-39 Ohms
Flow Range	Without PRS-D: 0.25 to 200 GPM (0,06 to 45,40 m3/h; 0,02 to 12,60 l/s) With PRS-D: 5 to 200 GPM (1,14 to 45,40 m3/h; 0,32 to 12,60 l/s)
Operating Pressure	20 to 200 psi (1,38 to 13,80 bars)

RainBird 150 PESB Valve with Pressure Regulating Module

Appendix B: Monthly Flow Meter Data

Compiled Data for Computing Potable Water and Energy Reduction (Gallons per month)

Month	Condensate In (FM #	Rainfall In	Rainfall Captured	Makeup In (FM #3)	Smart Plot Turf Out (FM #4)	Smart Plot Ground Cover Out (Station 34)	Station 33 % of total irrigation	Station 33 Makeup Gal Out	Overflow Out (FM #2)	Estimated Unmetered Overflow Out	Total Overflow Out	Control Plot	Tank Vol (Gal
Nov	0	0	0	74	80	209	0.28	20	180	334	514	100	11432
Dec	25	15378	3519	0	0	0	0.00	0	5436	6423	11859	694	14976
Jan2013	0	8441	102	0	0	102	0.00	0	3181	5158	8339	296	15078
Feb	0	0	0	0	0	794	0.00	0	0	0	0	1461	14284
Mar	0	7195	783	0	0	946	0.00	0	1599	3867	5466	2153	15067
Apr	165	0	0	0	855	1220	0.41	0	0	0	0	1846	13157
May	679	0	0	0	883	1478	0.37	0	0	0	0	2302	11475
Jun	907	0	0	0	1020	2374	0.30	0	0	0	0	2902	8988
Jul	1174	0	0	0	1013	3693	0.22	0	0	0	0	3118	5456
Aug	1011	0	0	2491	1716	1666	0.51	1264	0	0	0	3549	5576
Sept	1157	0	0	3236	2192	1725	0.56	1811	0	0	0	3329	6052
Oct	60	0	0	4290	1884	2016	0.48	2072	0	0	0	3496	6502
Nov	93	734	734	2820	455	1227	0.27	763	0	0	0	3160	7417
Dec	15	0	0	0	0	1155	0.00	0	0	0	0	3321	6163
Jan2014	0	0	0	0	0	1361	0.00	0.00	0	0	0	3137	4802
Feb	0	38371	11224	0	140	1184	0.11	0.00	9740	17407	27147	650	16026
Mar	0	7854	534	0	534	0	1.00	0.00	1277	6043	7320	77	14045
Apr	16	0	0	0	1459	1937	0.43	0.00	0	0	0	1377	10665
May	519	0	0	0	2873	3000	0.49	0.00	0	0	0	4477	5311
Jun	1886	0	0	3579	2843	2032	0.58	2087	0	0	0	4742	5901
Jul	3990	0	0	2577	3846	2564	0.60	1546.20	0	0	0	4970	6058
Aug	2202	0	0	2756	3296	2101	0.61	1683.12	0	0	0	4975	5619
Sept	3468	0	0	577	2730	2068	0.57	328.31	0	0	0	4767	4866
Oct	902	4818	4818	2783	1836	2115	0.46	1293.24	0	0	0	3237	9418
Nov	29	2303	2303	0	533	1752	0.23	0.00	0	0	0	2345	9465
Dec	153	42149	6478	0	0	0	0.00	0.00	17016	18655	35671	942	16096
Jan-15	0	15279	84	0	0	0	0.00	0.00	9301	5894	15195	24	16180
Feb	0	4451	-182	0	0	0	0.00	0.00	3526	1107	4633	0	15998
Total	18426	131594	26878	25109	30108	38510	0.44	12848	45640	58130	103770	66653	
2013	5261	16370	1619	12837	10018	18396	0.35	5910	4780	9025	13805	30933	
2014	13165	95495	25357	12272	20090	20114	0.50	6938	28033	42105	70138	35696	

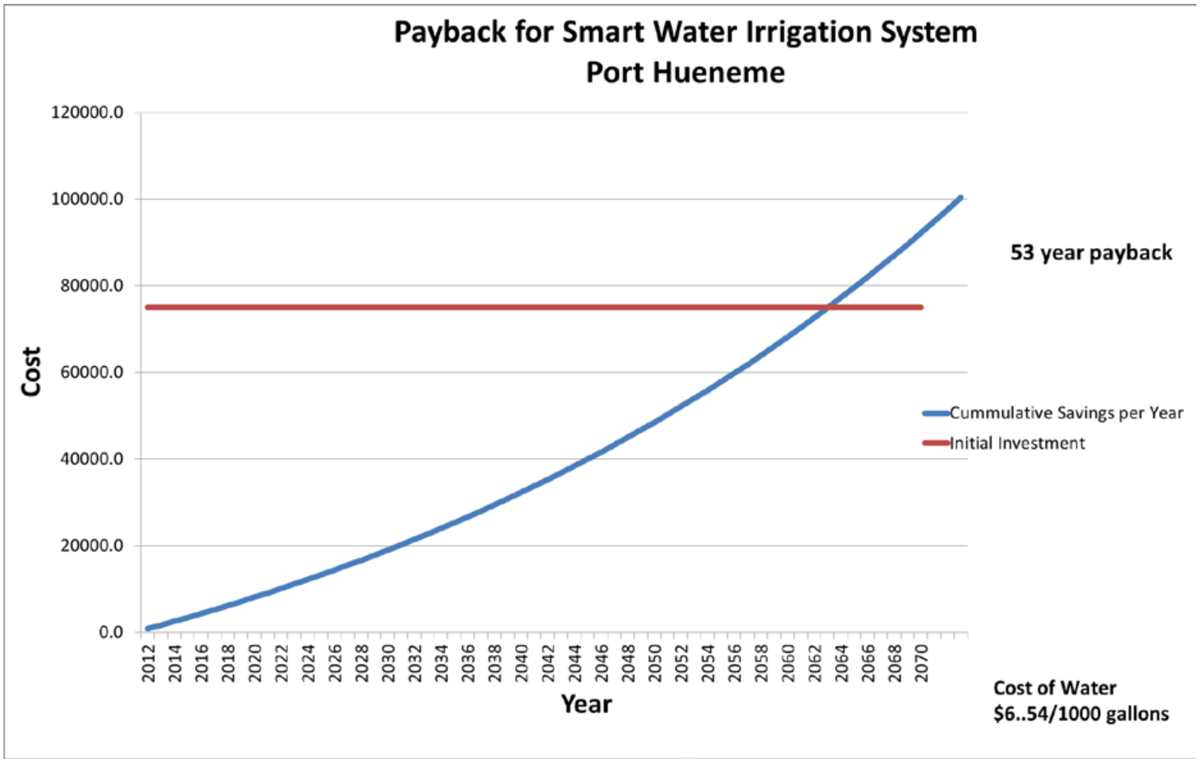


Appendix C: Life Cycle Cost for Smart Water Conservation System

Smart				Control					
Grass Area=	7560.0			Grass Area=	7560.0 ft2				
Smart Plot Volume per sc	23.0			Control Plot Volume per square foot.	52.0 in				
cost per foot (smart)	0.1			cost per foot (control)	0.2 per ft2				
year cost (control)	756.0			year cost (control)	1587.6			Delta Savings	831.6

Year	Inflation Rate	Water Cost Escalation	Capital costs	Water Savings w/smart Water System		Capital cost	Water Savings Totals (Cumulative)
2012	1.04	1.02	75000			75000.0	
2013	1.04	1.02	0	831.6	0.0	75000.0	831.6
2014	1.04	1.02	0	848.2	0.0	75000.0	1679.8
2015	1.04	1.02	0	865.2	0.0	75000.0	2545.0
2016	1.04	1.02	0	882.5	0.0	75000.0	3427.5
2017	1.04	1.02	0	900.2	0.0	75000.0	4327.7
2018	1.04	1.02	0	918.2	0.0	75000.0	5245.8
2019	1.04	1.02	0	936.5	0.0	75000.0	6182.4
2020	1.04	1.02	0	955.2	0.0	75000.0	7137.6
2021	1.04	1.02	0	974.4	0.0	75000.0	8111.9
2022	1.04	1.02	0	993.8	0.0	75000.0	9105.8
2023	1.04	1.02	0	1013.7	0.0	75000.0	10119.5
2024	1.04	1.02	0	1034.0	0.0	75000.0	11153.5
2025	1.04	1.02	0	1054.7	0.0	75000.0	12208.2
2026	1.04	1.02	0	1075.8	0.0	75000.0	13283.9
2027	1.04	1.02	0	1097.3	0.0	75000.0	14381.2
2028	1.04	1.02	0	1119.2	0.0	75000.0	15500.4
2029	1.04	1.02	0	1141.6	0.0	75000.0	16642.0
2030	1.04	1.02	0	1164.4	0.0	75000.0	17806.5
2031	1.04	1.02	0	1187.7	0.0	75000.0	18994.2
2032	1.04	1.02	0	1211.5	0.0	75000.0	20205.7
2033	1.04	1.02	0	1235.7	0.0	75000.0	21441.4
2034	1.04	1.02	0	1260.4	0.0	75000.0	22701.8
2035	1.04	1.02	0	1285.6	0.0	75000.0	23987.5
2036	1.04	1.02	0	1311.3	0.0	75000.0	25298.8
2037	1.04	1.02	0	1337.6	0.0	75000.0	26636.4
2038	1.04	1.02	0	1364.3	0.0	75000.0	28000.7
2039	1.04	1.02	0	1391.6	0.0	75000.0	29392.3
2040	1.04	1.02	0	1419.4	0.0	75000.0	30811.8
2041	1.04	1.02	0	1447.8	0.0	75000.0	32259.6
2042	1.04	1.02	0	1476.8	0.0	75000.0	33736.4
2043	1.04	1.02	0	1506.3	0.0	75000.0	35242.7
2044	1.04	1.02	0	1536.5	0.0	75000.0	36779.2
2045	1.04	1.02	0	1567.2	0.0	75000.0	38346.4
2046	1.04	1.02	0	1598.5	0.0	75000.0	39944.9
2047	1.04	1.02	0	1630.5	0.0	75000.0	41575.4
2048	1.04	1.02	0	1663.1	0.0	75000.0	43238.5
2049	1.04	1.02	0	1696.4	0.0	75000.0	44934.9
2050	1.04	1.02	0	1730.3	0.0	75000.0	46665.2
2051	1.04	1.02	0	1764.9	0.0	75000.0	48430.1
2052	1.04	1.02	0	1800.2	0.0	75000.0	50230.3

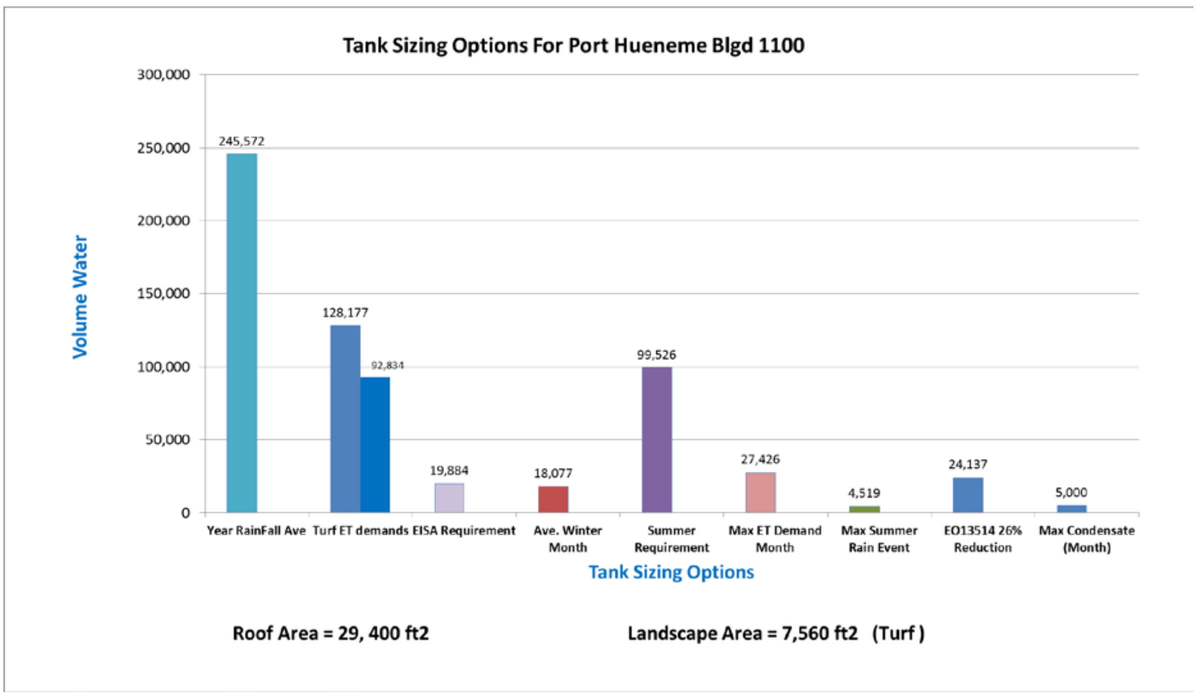
Year	Inflation Rate	Water Cost Escalation	Capital costs	Water Savings w/smart Water System		Capital cost	Water Savings Totals (Cumulative)
2053	1.04	1.02	0	1836.2	0.0	75000.0	52066.5
2054	1.04	1.02	0	1872.9	0.0	75000.0	53939.4
2055	1.04	1.02	0	1910.4	0.0	75000.0	55849.8
2056	1.04	1.02	0	1948.6	0.0	75000.0	57798.4
2057	1.04	1.02	0	1987.6	0.0	75000.0	59786.0
2058	1.04	1.02	0	2027.3	0.0	75000.0	61813.3
2059	1.04	1.02	0	2067.9	0.0	75000.0	63881.2
2060	1.04	1.02	0	2109.2	0.0	75000.0	65990.4
2061	1.04	1.02	0	2151.4	0.0	75000.0	68141.8
2062	1.04	1.02	0	2194.4	0.0	75000.0	70336.2
2063	1.04	1.02	0	2238.3	0.0	75000.0	72574.6
2064	1.04	1.02	0	2283.1	0.0	75000.0	74857.6
2065	1.04	1.02	0	2328.8	0.0	75000.0	77186.4
2066	1.04	1.02	0	2375.3	0.0	75000.0	79561.7
2067	1.04	1.02	0	2422.8	0.0	75000.0	81984.6
2068	1.04	1.02	0	2471.3	0.0	75000.0	84455.9
2069	1.04	1.02	0	2520.7	0.0	75000.0	86976.6
2070	1.04	1.02	0	2571.1	0.0	75000.0	89547.7
2071	1.04	1.02	0	2622.6	0.0	75000.0	92170.3
2072	1.04	1.02	0	2675.0	0.0	75000.0	94845.3
2073	1.04	1.02	0	2728.5	0.0	75000.0	97573.8
2074	1.04	1.02	0	2783.1	0.0	75000.0	100356.8
2075	1.04	1.02	0	2838.7	0.0	75000.0	103195.6
2076	1.04	1.02	0	2895.5	0.0	75000.0	106091.1
2077	1.04	1.02	0	2953.4	0.0	75000.0	109044.5
2078	1.04	1.02	0	3012.5	0.0	75000.0	112057.0
2079	1.04	1.02	0	3072.7	0.0	75000.0	115129.7
2080	1.04	1.02	0	3134.2	0.0	75000.0	118263.9
2081	1.04	1.02	0	3196.9	0.0	75000.0	121460.8
2082	1.04	1.02	0	3260.8	0.0	75000.0	124721.6
2083	1.04	1.02	0	3326.0	0.0	75000.0	128047.7
2084	1.04	1.02	0	3392.6	0.0	75000.0	131440.2
2085	1.04	1.02	0	3460.4	0.0	75000.0	134900.6
2086	1.04	1.02	0	3529.6	0.0	75000.0	138430.2
2087	1.04	1.02	0	3600.2	0.0	75000.0	142030.4


Payback for Smart Water Irrigation System
Port Hueneme
120000.0
100000.0
80000.0
60000.0
40000.0
20000.0
0.0
Cost
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
2052
2054
2056
2058
2060
2062
2064
2066
2068
2070
Year
53 year payback
Cummulative Savings per Year
Initial Investment
Cost of Water
$6..54/1000 gallons

Appendix D: Tank Sizing Spreadsheet

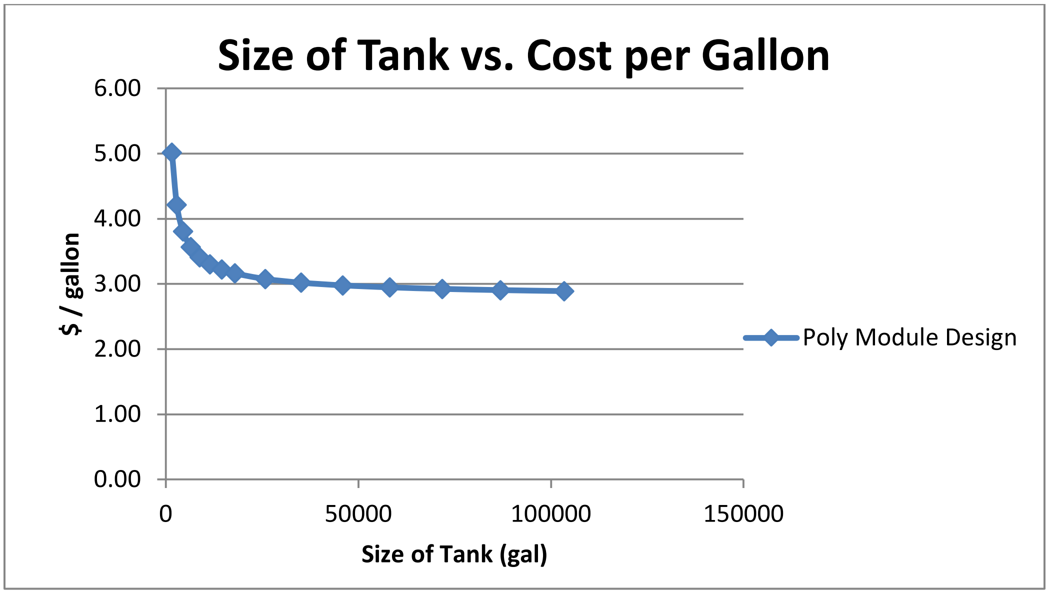
Use Excel Spreadsheets to evaluate tank size options.

Tank sizing Considerations	Units	Notes
Average rain	14.3	Data Aquired From NOAA
Roof area	29400	Blgd Info
Turf Area	7560	Bldg Info
Ground Cover Area	2068	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Ground Cover Area ET Year	0	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Rainfall Roof Loss factor	0.9	Storm Water Design
Turf ET yr demand	34	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Turf ET summer	21.12	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Turf ET (Summer hightest)	5.82	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Irrigation Efficiency	0.8	Estimate
95 percentile Storm	1.1	Calculated from NOAA or other storm water Databases
Average winter Rain Event	1	Historical information
Max Winter Rain Cumulative (month)	3.43	ET Database- Local Center of Irrigation Technology or Irrigation Tech Center.
Max Summer Rain Event	0.25	Historical information
Reduction Goal 26%	0.26	Executive Order
Max Monthly condensate	5000	Validated condensate capture from 2 20 Ton HVAC units in Port Hueneme, CA



EISA Tank Size Determination		
Roof size	29,000	FT2
95 percentile Storm (30 year Period)	1.1	Inches -Historic Information
Tank Volume per EISA Requirment	19,884	Gallons

For Modular Tanks use the graph or table below to estimate tank cost relative to size.



size of tank (gal)	17952
size of tank (ft^3)	2500
depth of tank (ft)	6
width and length (f	20.41241452
surface area (ft^2)	1323.231282
dirt removed (ft^3)	2500
dirt backfilled (ft^3)	833.3333333
size of hole (ft^3)	3333.333333
bottom of tank (ft^2)	416.6666667
liner coefficient (ft	906.5646152
# of modules	348.2379161

dimensions	Total Gallons	Total Cost	Total Cost per gallon
6*6*6	1615	8,100	5.02
8*8*6	2872	12,097	4.21
10*10*6	4488	17,078	3.81
12*12*6	6462	23,042	3.57
14*14*6	8796	29,993	3.41
16*16*6	11489	37,929	3.30
18*18*6	14541	46,849	3.22
20*20*6	17952	56,754	3.16
24*24*6	25850	79,516	3.08
28*28*6	35185	106,219	3.02
32*32*6	45957	136,863	2.98
36*36*6	58164	171,444	2.95
40*40*6	71808	209,966	2.92
44*44*6	86887	252,424	2.91
48*48*6	103403	298,824	2.89

Use spreadsheet below to determine payback on installing a Smart Water Conservation System.

SITE CONDITIONS/ASSUMPTIONS	Data	UNITS/NOTES
Climate	Mediterranean	
Roof Area (plan view)	29,000	FT2
Turf Size (Combined Track, Football and Soccer Field)	7,500	FT2
Average Rain Per year	14	Inches/year
Rainwater Available @ 50% normal	129,395	gallons
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	Inches/year
Average Summer ET requirement for Turf	21	Inches
Retrofit or New Construction	Retrofit	
HARVEST TANK INFORMATION		
Harvest Tank (Estimated Cost per gallon $1.50 -$3.00)	$3.13	Material and Installation Cost
Estimated size of tank	20000	gallons
Tank Service life	50	years
UTILITIES UNIT COST		
Water Cost	$35.00	Cost per 1000 gallons
Electrical cost	$0.14	Cost per KW-h
SMART WATER SYSTEM COMPONENTS		
Capital Cost of Calsense Controller ($5000)	$5,000	
Capital Cost of pump package and makuep water($4141)	$4,141	
Capital Cost of Water Harvest Component (Size dependen	$62,600	
Capital Cost of First Flush and Ancillary (5% or Water Harv	$3,130	
Smart Oper and Maint. cost (10hours per year)	$450	
Smart Training (One time only)	$360	
If function: No harvest tank = 0, If tank size > 0 = 1	1	
Capital Cost (Retrofit)	**$75,681**	
Capital Cost (New Construction)	**$0**	
VOLUME OF WATER NEEDED		
Average Water Demand (ET Demand -Rainwater)	20	inches
Irrigation Efficiency of Smart Water System	0.50	From Demonstration
Total water Needed for Satisfactory Turf (Timer Based)	184,195	gallons
Total irrigated water Needed for Satisfactory Turf (Smart)	92,098	gallons
Water Harvest Tank efficiency Factor	1.5	From Demonstration
Economic Analysis Results		
Water Cost annual increase (2% escalation)	0.02	Percentage
STATUS QUO: Timer- (Potable Water Cost Year 1)	$6,447	
SMART PLOT: (Potable Water Cost Year 1)	$2,173	
SMART PLOT: (Electrical Cost)	$11	
Cost Avoidance (Year 1)	$3,812	
Water reduction (Percent) reduced by Tank	32.57%	Percentage
Payback (Retrofit)	**19.9**	**years**
Payback (New Construction)	**0.0**	**years**

Appendix E: Audit from Center for Irrigation, Cal State Fresno

Turfgrass Evaluation for

Smart Water Conservation System for Irrigated Landscape Naval Facilities Engineering and Expeditionary Warfare Center Project Manager: Mr. Gary Anguiano Evaluators: Dr. Charles Krauter and Dr. John Bushoven, California State University, Fresno

November 4, 2015

Objective:

Evaluate turf health and aesthetics using turf protocols developed by the National Turf Evaluation Program Required (NTEP) Protocols, Standards and Applications for the Visual Field Assessment of Turf Grasses using the following criteria.

- If the aesthetic assessment rating of the smart plot was greater than or equal to the aesthetic assessment rating of the control plot, then the smart water conservation system did not achieve this performance objective.
- If the aesthetic assessment rating of the smart plot was less than the aesthetic assessment rating of the control plot, then the smart water conservation system did not achieve this performance objective.

Protocol:

Components of Turfgrass Condition Assessed (Good, Medium, Poor):

- Uniformity – Turfgrass uniformity is the degree to which a turfgrass community is free from variation in color, density, texture, and growth habit. Non-uniform turf may occur because of a heterozygous plant population, off-type seed or vegetative segments contaminating a uniform plant population, non-uniform seed distribution or establishment, non-uniform fertilizer or pesticide applications, abiotic and biotic injury, and/or cultural accidents i.e. scalping, chemical burns, etc. In most cases, a planting having low uniformity (regardless of the cause) will have a long lasting effect on the quality score. This negative influence on quality is scored as such until the turfgrass planting has changed its phenotype or recovered from injury to a more uniform planting. This record of injury is especially critical when biotic stresses are responsible for poor turfgrass uniformity.
- Color – Color is usually the first component of turfgrass quality recognized by raters and consumers. Color is a visual perception of light reflected or emitted by a turfgrass planting. The light emitted from the planting results from to a composite of turfgrass and weed pigments (chlorophyll, anthocyanin, and carotene) combined with a background reflection of soil and dying and dead leaves. Human preference of turfgrass color generally favors hues of green, bluish green or greenish blue having high saturation and moderate brightness. In most situations, a dark green color surpasses a light green or yellow-green color and should translate to high quality scores.

Assessment Parameters:

Time of Day - The time of day is the time period during the daylight hours when the rater is required to conduct a VFA. NTEP's required protocol for the assessment time period is from 10:00 AM to 3:00 PM. This period is selected to avoid the early morning and evening hours when light quality is altered by the low angle of the sun's rays passing through high concentrations of the earth's atmosphere. Quality components assessments of color, shoot density, and leaf texture are most affected by the time of day.

Sky Condition – The sky condition is the absence or presence of clouds in the sky during the time period the rater is conducting a VFA. NTEP's required protocol for optimal sky condition for assessing a turfgrass planting is overcast. An overcast sky condition dampens the brightness of the sunlight and reduces radiant glare from leaf surfaces and reduces interleaf shadowing. The alteration of light quality due to radiation passing through an overcast sky is recognized as a potential artifact in scoring quality; however the glare of the sunlight from the grass and the interleaf shadowing surpasses the negative effects of altered light quality.

Orientation to the Sun – The orientation to the sun is the person's view of the turfgrass planting as either face-to-the-sun or back-to-the-sun. Orientation to the sun is only considered when the assessment of a turfgrass planting is made under full sun due to a geographic location dominated by full sun or a rater's time schedule that restricts his or her choices on day selection. NTEP's required protocol for orientation to the sun is the rater's view is back-to-the-sun. Back-to-the-sun reduces the sun's brightness on the rater's vision and the indirect reflection from the rater's recording paper (usually white).

Components of Irrigation System Assessed:

- Christiansen's Coefficient of Uniformity (CU): CU for an irrigated area is determined from a catch can study and then application of the formula given below. (If the irrigation time at each measurement point is the same, then it does not matter whether the application rate or application amount is measured.) It is assumed that the application measurement points are located so that each point represents the same size area as the others.

CU = 100 (1 - D/M)
D = (1/n) å | Xi - M| M = (1/n) å Xi
where
CU = Christiansen's Coefficient of Uniformity (%) D = Average Absolute Deviation from the Mean
M = Mean Application
Xi = Individual Application Amount
n = Number of Individual Application Amounts
å = Symbol for Summation
| | = Symbol for Absolute Value of Quantity between the Bars

The absolute value of a deviation considers only its magnitude, not its sign. For example, deviations of two units above the mean and two units below the mean both have absolute deviations of two.

- Distribution Uniformity (DU): In using this approach, all the individual application data points are sorted from high to low values. The lowest 25% of the values are identified, and the average of these (the "low quarter, as it's sometimes referred to) is divided by the mean application for the entire area, and multiplied by 100 to convert to percent. Thus a DU of, say, 80 means that the low quarter of the applications averaged 20% lower than the mean application. However, this method does not take into account the location of the low application values, or any benefit which might be derived from higher applications immediately adjacent to the low values. The "low quarter" might be made up of one relatively large area in deficit, or it might be from several smaller deficit areas. Also DU would still be considered an average measure, since it describes the average of a relatively large area (25% of the total), rather than describing the worst case situation. The use of the "lowest 25%" is purely arbitrary and bears no relationship to the crop's growing characteristics.
- Relative Soil Moisture: Determined with the Aquaterr M350 Digital Soil Moisture Meter

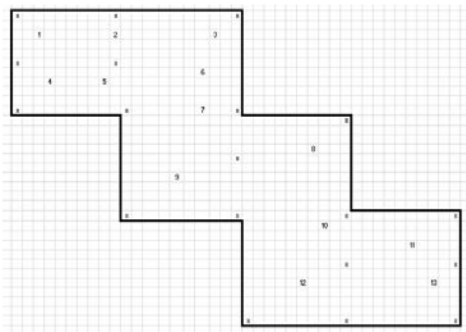
*** All photographs provided by G. Anguiano**

Results:

May 16, 2013 (1000-1300) Assessment:

Smart Plot

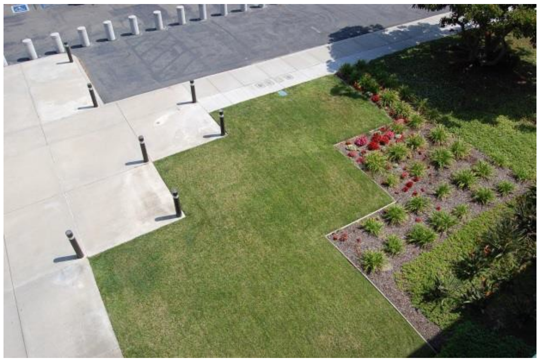
Aerial photograph from rooftop



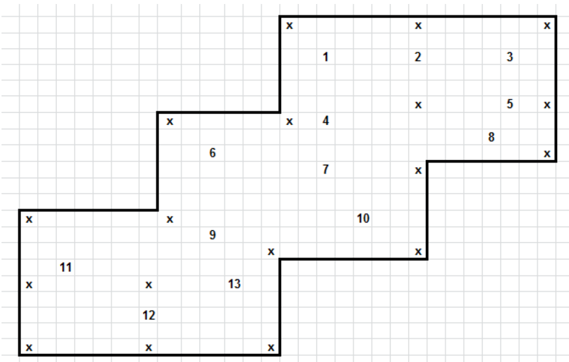
Catch	Turf condition	Soil probe	s = shallow		ppt/15min	rate in/hr	dev
1	good	85			0.16	0.64	0.11
2	good	81		0.20		0.80	0.07
3	good	78		0.22		0.88	0.05
4	poor	70	s		0.30	1.20	0.03
5	medium	78	s		0.25	1.00	0.02
6	good	70	s		0.32	1.28	0.05
7	medium	78	s		0.32	1.28	0.05
8	medium	75	s		0.28	1.12	0.01
9	poor	77	s		0.28	1.12	0.01
10	poor	83	s		0.26	1.04	0.01
11	good	90			0.23	0.92	0.04
12	medium	81	s		0.30	1.20	0.03
13	good	64			0.43	1.72	0.16
				average	0.27	1.09	0.05
				CU =	0.82		
				DU =	0.74		

Summary: Poor turf was primarily a sparse stand with bare ground between the blades of grass. The "s" was determined from the depth to which the soil water probe could be pushed into the turf. The shallow readings were well correlated with poor turf. The soil water probe was not calibrated and the depth to which it could be inserted was variable so these readings are not likely to be representative of actual soil moisture levels. The turf rated "good" was either in shade (1,2,3) or where the water application was significantly higher than average (6,11, 13) indicating the probability that the medium and poor areas are water stressed. The uniformity of the system is good. The average application rate is 1.09 inches per hour so the 5 minute sprinkler run will apply an average of 0.09 inches of water. Therefore, accumulated Et / 0.09 = the number of 5 minute runs required based on the average precipitation rate.

Control Plot



Aerial photograph from rooftop



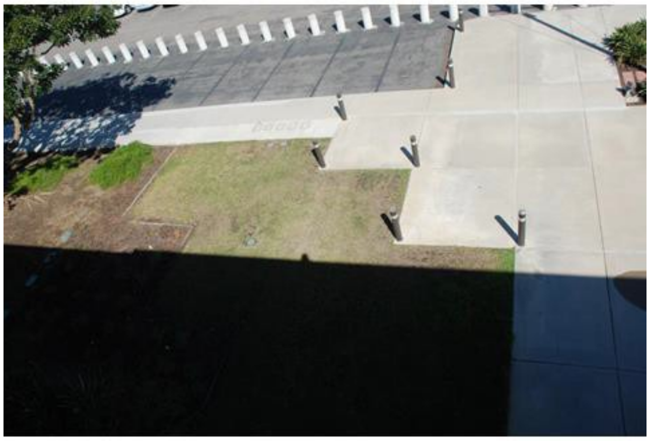
Catch	Turf condition	Soil probe s = shallow		ppt/15min	rate in/hr	dev
1	good	88		0.14	0.56	0.20
2	good	92		0.40	1.60	0.06
3	good	83		0.30	1.20	0.04
4	good	69		0.41	1.64	0.07
5	good	82		0.12	0.48	0.22
6	good	88		0.58	2.32	0.24
7	good	85		0.28	1.12	0.06
8	medium	85		0.38	1.52	0.04
9	medium	75		0.75	3.00	0.41
10	medium	67		0.38	1.52	0.04
11	poor	96	s	0.12	0.48	0.22
12	good	88		0.39	1.56	0.05
13	good	81		0.22	0.88	0.12
			average	0.34	1.38	0.14
			CU =	0.60		
			DU =	0.44		

Summary: Poor turf was primarily a sparse stand with bare ground between the blades of grass. Turf appearance was very good and reasonably uniform with the exception of a sparse area near catchment 11. The sprinkler head near catchment 11 was damaged and did not extend high enough to distribute the sprinkler pattern properly. The uniformity of the system is low but that is primarily due to adjustments in heads to avoid overspray. With the exception of the small area around catchment 11, the system appears to apply sufficient water, possibly more than sufficient.

October 3, 2015 (0900-1100) Assessment:

Soil, thatch and moisture sampling methodology (Aquaterr M350 Digital Soil Moisture Meter in foreground)

Smart Plot



Aerial photograph from rooftop

Street level photograph

Soil core indicating moderate moisture penetration and little thatch development

Control Plot

Aerial photograph from rooftop

Soil core indicating good moisture penetration and little thatch development

Summary: No anomalies in irrigation system operation were observed, sprinkler head performance appeared normal with no significant coverage deficiencies. Turf uniformity, weed presence, thatch presence, and relative soil moisture were assessed and little difference was observed between the smart and control plots.

Broadleaf weed pressure was; however, greatest on the SE corner of the smart plot, most likely due to turf death following pump failure, and significant shading from building. Smart plot turf height and uniformity was slightly less than that of the control plot, but again this was likely due to pump failure that occurred between first and final assessment, and subsequent turf death. Turf quality for both plots was still considered acceptable (as utility turf).

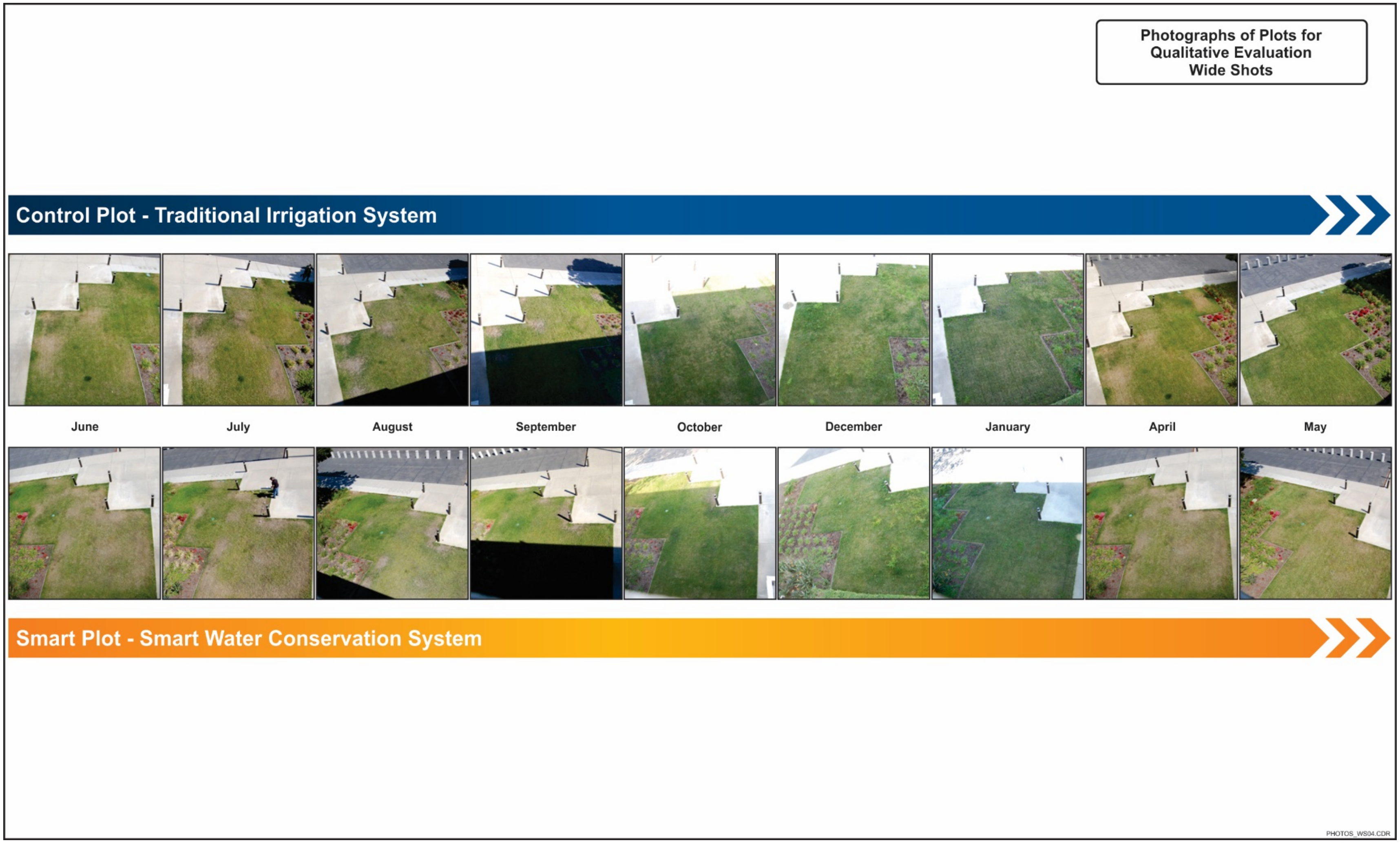
Subsequent performance evaluation following turf re-establishment, including over-seeding and broadleaf herbicide application is recommended, but as of October 2015 the aesthetic assessment rating of the smart plot is at a minimum equal to the aesthetic assessment rating of the control plot. Installation of additional soil moisture sensors may be advisable in non- uniform areas (shaded-unshaded). Thus if functioning properly it appears the smart controller system is capable of maintaining quality as appropriate for utility turf - aesthetically pleasing groundcover with reduced water and maintenance needs.

Turf Quality Assessment

Initial site visit: Control
= 7/Smart = 7

Final site visit:
Control = 7/ Smart = 6 (minimally acceptable value)

Appendix F: Photos of the Control and Smart Plot throughout the Demonstrations



Photographs of Plots for
Qualitative Evaluation
Wide Shots
Control Plot - Traditional Irrigation System
June
July
August
September
October
December
January
April
May
Smart Plot - Smart Water Conservation System
PHOTOS_WS04.CDR


Photographs of Plots for
Qualitative Evaluation
Close Ups
Control Plot - Traditional Irrigation System
June
July
August
September
October
December
January
April
May
Smart Plot - Smart Water Conservation System
PHOTOS_CU04.CDR

Appendix G: Return on Investment Spreadsheet Notes

SITE CONDITIONS/ASSUMPTIONS	Data	UNITS/NOTES
Climate	Mediterranean	Pull Down- Port Hueneme is considered Mediterranean Climate
Roof Area (plan view)	23,600	Area can be taken from drawings or determined from field measurements
Turf Size (Combined Track, Football and Soccer Field)	35000	Area can be taken from drawings or determined from field measurements
Average Rain Per year	14	Data captured from NOAA data
Rainwater Available @ 50% normal	105,301	Calculation used for evaluating tank size options
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	Monthly Et demand data captured from Regional Irrigation Centers
Average Summer ET requirement for Turf	21	Determined from Et charts
Retrofit or New Construction	Retrofit	User Selection (retrofit or new construction)
HARVEST TANK INFORMATION		
Harvest Tank (Estimated Cost per gallon $1.50 -$5.00)	$3.11	Automatically updates based on Estimated Tank Size
Above ground or Below ground	Below Ground	User Selection (below or above ground tank)
Estimated size of tank	20000	User Selects from pulldown. Compare With EISA spreadsheet below.
Tank Service life	50	Estimated tank life if underground
Estimate of total yearly volume of Condensate	15000	Use actual data if possible or use condensate spreadsheet on internet.
UTILITIES UNIT COST		
Water Cost	$6.54	User input based on regional water cost.
Electrical cost	$0.14	User input based on regional electrical cost.
SMART WATER SYSTEM COMPONENTS		
Capital Cost of Calsense Controller ($5000)	$5,000	Data from demonstration- (Review based on chosen site)
Capital Cost of pump package and makuep water($4141)	$4,141	This is an estimate based on demonstration
Capital Cost of Water Harvest Component (Size dependent)	$62,200	Calculated based on tank size and conditions above.
Capital Cost of First Flush and Ancillary (5% or Water Harvest)	$3,110	This is an estimate based on demonstration
Smart Oper and Maint. cost (1 hours per year)	$50	This is an estimate based on demonstration
Smart Training (One time only)	$60	This is an estimate based on demonstration
If function: No harvest tank = 0, If tank size > 0 = 1	1	Routine needed for excel spreadsheet
Capital Cost (Retrofit)	**$74,561**	
Capital Cost (New Construction)	**$0**	
VOLUME OF WATER NEEDED		
Average Water Demand (ET Demand -Rainwater)	20	Calculated value
Irrigation Efficiency of Smart Water System	0.50	This is an estimate based on demonstration
Total water Needed for Satisfactory Turf (Timer Based)	859,577	This is an estimate based on demonstration
Total irrigated water Needed for Satisfactory Turf (Smart)	429,788	This is an estimate based on demonstration
Water Harvest Tank efficiency Factor	1.5	This is an estimate based on demonstration
Total Potable water for turf Plot	384,788	This is an estimate based on demonstration
Economic Analysis Results		
Water Cost annual increase (2% escalation)	0.02	Not used in this spreadsheet. Final assessment should include.
STATUS QUO: Timer- (Potable Water Cost Year 1)	$5,622	Calculated value
SMART PLOT: (Potable Water Cost Year 1)	$2,517	Assumes that potable water is needed
SMART PLOT: (Electrical Cost)	$52	Calculated value
Cost Avoidance (Year 1)	$3,003	Calculated value
Water reduction (Percent) reduced by Tank	6.98%	Calculated value used to evaluate benefit of water harvesting.
Payback (Retrofit)	**24.8**	**years**
Payback (New Construction)	**0.0**	**years**

Appendix H: Cost of Calsense and Baseline Controllers and Accessories

New Installation Scenario 1 (Capital Cost for ET Controller, ET sensor hardwired to Controller and Water Saving Accessories)

Nomenclature	Unit cost	Available On-Site	New Installation
Model ET 2000e 48 Station	$3,950.00	No	$3,950.00
Stainless Enclosure W/ Dome Attenae and Transient protection	$2,360.00	No	$2,360.00
ETg Interface	$475.00	No	$475.00
Rain Bucket Interface	$475.00	No	$475.00
ET Gauge	$1,375.00	No	$1,375.00
Stainless Steel Enclosure for ET gauge	$995.00	No	$995.00
Calsense Tipping Rain Bucket	$595.00	No	$595.00
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna, with NO antenna cable	$190.00	NA	
ET Communication via anlog phone line	$610.00	NA	
ET Communication via website (ethernet)	$1,000.00	NA	
ET Communication Via Radio Signal	$1,500.00	NA	
Installation (estimated)			$4,000.00
			$15,030.00

New Installation Scenario 2 (Capital Cost for ET Controller, accessing shared on-Site ET sensor data via Analog, and Water Saving Accessories)

Nomenclature	Unit cost	Available On-Site	New Installation
Model ET 2000e 48 Station	$3,950.00	No	$3,950.00
Stainless Enclosure W/ Dome Attenae and Transient protection	$2,360.00	No	$0.00
ETg Interface	$475.00	No	$0.00
Rain Bucket Interface	$475.00	No	$475.00
ET Gauge	$1,375.00	Yes	$0.00
Stainless Steel Enclosure for ET gauge	$995.00	Yes	$0.00
Calsense Tipping Rain Bucket	$595.00	Yes	$595.00
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna, with NO antenna cable	$190.00	No	$190.00
ET Communication via anlog phone line	$610.00	No	$610.00
ET Communication via website (ethernet)	$1,000.00	N/A	
ET Communication Via Radio Signal	$1,500.00	N/A	
Installation (estimated)			$3,500.00
			$10,125.00
Note: ET communicaiton with analog lines is not recommended for sites with numerous controllers due to long data download times.			
Based on 2011 data			

New Installation Scenario 3 (Capital Cost for ET Controller, accessing shared on-Site ET and rain data via Radio, and Water Saving Accessories)

Nomenclature	Unit cost	Available On-Site	New Installation
Model ET 2000e 48 Station	$3,950.00	No	$3,950.00
Stainless Enclosure W/ Dome Attenae and Transient protection	$2,360.00	No	$2,360.00
ETg Interface	$475.00	N/A	
Rain Bucket Interface	$475.00	N/A	
ET Gauge	$1,375.00	Yes	
Stainless Steel Enclosure for ET gauge	$995.00	Yes	
Calsense Tipping Rain Bucket	$595.00	Yes	
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna, with NO antenna cable	$190.00	No	$0.00
ET Communication via anlog phone line	$610.00	N/A	
ET Communication via website (ethernet)	$1,000.00	N/A	
ET Communication Via Radio Signal	$1,500.00	Yes	$1,500.00
Installation (estimated)			$3,000.00
			$11,615.00

New Installation Scenario 4 (Capital Cost for ET Controller and Accessories with ET downloaded from Website) Not applicable to DoD sites do to security reasons.

Nomenclature	Unit cost	Available On-Site	New Installation
Model ET 2000e 48 Station	$3,950.00	No	$3,950.00
Stainless Enclosure W/ Dome Attenae and Transient protection	$2,360.00	No	$2,360.00
ETg Interface	$475.00	N/A	
Rain Bucket Interface	$475.00	No	$475.00
ET Gauge	$1,375.00	N/A	
Stainless Steel Enclosure for ET gauge	$995.00	N/A	
Calsense Tipping Rain Bucket	$595.00	N/A	$475.00
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna, with NO antenna cable	$190.00	N/A	
ET Communication via anlog phone line	$610.00	N/A	
ET Communication via website (ethernet)	$1,000.00	No	$1,000.00
ET Communication Via Radio Signal	$1,500.00	N/A	
Installation (estimated)			$3,000.00
			$12,065.00

New Installation Scenario 5 (Capital Cost for Baseline Soil moisture Based ET Controller and Accessories)

Nomenclature	Unit cost	Available On-Site	New Installation
Irrigation Controller, System 3200, (200 zones, 8 Master V), Qty 1		No	
Flow meter with Bicoder, Qty 2		No	
Soil Moisture Sensor, Qty 4		No	
Surge Arrestor, Qty 1		No	
Bicoder for Master Valve (BL 5201MV), Qty 2		No	
Bicoder for Zone Valve (BL 5201), Qty 30		No	
			$7,485.00
.			
Installation (estimated)			$3,000.00
			$10,485.00

Retrofit Scenario 1 - Capital Cost to retrofit Existing ET Controller at Port Hueneme with water saving accessories

Nomenclature	Unit cost	Exist.Equipment on-site at Building 1100 or on Base	Retrofit Building 1100
Model ET 2000e 6 Station	$3,950.00	Yes	$0.00
Stainless Enclosure W/ Dome Attenae and Transient protection	$2,360.00	Yes	$0.00
ETg Interface	$475.00	Yes	$0.00
Rain Bucket Interface	$475.00	Yes	$0.00
Transient Protect Package	$735.00	Yes	$0.00
ET Gauge	$1,375.00	Yes	$0.00
Stainless Steel Enclosure for ET gauge	$995.00	Yes	$0.00
Calsense Tipping Rain Bucket	$595.00	Yes	$0.00
Flow meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio stick antenna	$190.00	No	$190.00
Communication (Phone line/Ethernet Device)*	$925.00	NA	$0.00
Communication Hub	$1,850.00	Yes	$0.00
Dash F Option	$1,000.00	No	$1,000.00
Installation (estimated)			$3,000.00
			$4,995.00

* Currently not available to DoD due to IT restrictions but used extensively in the private sector.

Appendix I: Technology Transfer

Technology Transfer Discussion

Technology Transfer:

Technology transfer (T2) of technologies developed through RDT&E programs, including ESTCP, can often be quite challenging. Depending on the ESTCP program area, the technology transfer specialist may have a difficult time identifying the appropriate community of end-users and stakeholders necessary to be successful. Some of the hurdles to the technology transfer specialist include:

1. Understanding the technology and its uses.
2. Identifying what methods and venues can be used to distribute the technology effectively.
3. Preparing list of relevant POC's.
4. Competition with vendor products and services.
5. Convincing potential customers to take time out of their busy schedules to review the technology.

The act of securing funding to help the customer acquire the technology for their facility or installation is most often the greatest hurdle to overcome.

If acquisition of the technology is being seriously considered by the customer, they should be provided with an acquisition package to help facilitate the process. The acquisition package is an innovative T2 product that contains examples of filled out forms, SOWs, cost estimates, permits and check lists that help guide the customer through the acquisition process. Customers should be told about potential funding sources, including the Utility Energy Service Contract O&M funds, which require payback in less than 10 years, and California Proposition 1 funds, which include storm water grants.

Target Audience:

Primary target groups for technology transfer are DoD communities consisting of, but not limited to, energy, publics works, and environmental managers. O&M and MILCON engineering managers, Facility POC's, and water and stormwater managers identified by database tools are all specifically identified targets. Communication to targeted audience will help deliver the technology needed in a form easily understood. The data bases to be used include MILCON, EPR Portal, USAF Automated Civil Engineering System-Project Management (ACES-PM), Naval Facilities Engineering Command eClient & eProjects.

Databases for Technology Transfer:

Some of the databases to help identify potential end-users and stakeholders include:

<u>MILCON</u> – DoD construction projects greater than $1M that require Congressional approval.

EPR Portal - A web site resource that contains database modules focusing on CWA/SDWA water quality, CAA air quality, RCRA hazardous waste and RCRA solid waste. The modules contain POCs who report compliance based data to help analyze Navy compliance performance, identify needs, formulate guidance, and seek Navy-wide solutions.

ACES-PM - USAF Automated Civil Engineering System-Project Management lists all construction projects, O&M and MILCON.

eClient - Naval Facilities Engineering Command – Similar to eProjects.

eProjects - Naval Facilities Engineering Command; Holds most Work inducted by NAVFAC, and links this work to funding, contract action, location, and various other attributes to assist in workload management and planning.

Approach:

Well-crafted emails with pertinent links from the NAVFAC EXWC website or other DoD technology development centers should be sent to the potential end-users. Email distribution lists should be developed from the databases described above.

EXWC successfully transferred the ESTCP developed NoFoam technology by combing emails and following up with phone calls. Initially, emails were sent out to potential targets, following by a phone call 1-2 days later. Over the phone, the technology was described in detail, and then further information was sent via with follow-up emails.

Technology transfer information products should be developed to assist engagement with customers and stockholders. Emails should be short and easy to read, with linked or attached technology transfer products, such as a brief video. Where interest is shown, further information should be given, including the final ESTCP report. If a customer desires implementation, identify site adaptions, funding, and then track the projects as they develop and provide necessary support to the DoD facilities.

Technology transfer tools are necessary to plan and document the technology transfer approach options, identification of stakeholder POCs, end-user listings, provide a record of customer engagement and the subsequent results and lesson's learned from those engagements.

Technology Integration Plan: A tool used to document necessary information and planning options to increase the level of successful technology transfer. A plan will typically include a brief technology description and a technology's demonstration project description. The plan details are mainly focused on categories such as overall implementation vision, implementation goal schedule, listing of stakeholders and technical authorities, integration risks, post-demonstration procurement funding options, customer marketing, operational requirements, installation requirements, environmental documentation, maintenance/calibration requirements, intellectual property, Logistics, Technical documentation and economic analysis. To facilitate the creation of a Technology Integration Plan, a set of digital forms incorporated into database application called the "Technology Integration Plan" (TIP) was developed in a user friendly format.

TIP report: As a function of the TIP database application, a TIP report can be generated by a single click of a button. The function consolidates the information entered into the database for a subject technology and creates a document in a report format for distribution to interested parties.

Customer Communication Journal: The customer communication journal allows the technology transfer specialist to document phone calls, organized email, create outlook reminders to contact customers and establish notes in a straight forward fashion and with user-friendly retrieval functionality.

Technology transfer informational products (i.e. marketing material) in various media formats have been used in both the private sector and to some extent in the DoD to inform customers or end-users of product solutions to address their pressing needs with varying degrees of success. The technology transfer specialist will produce informational material in a wide range of formats, due to the varying preferences customers have when choosing what form in which they want to digest information from and the venue at which they are being presented the information. Customers have a limited amount of time they feel they can invest looking at a promising technology or approach that may or may not solve an issue they may or may not have. It is therefore necessary to produce brief yet informative products that will engage the viewer/reader within the first couple of minutes. The goal is to entice the customer to ask for ever increasing detailed information of the technology or product eventually leading to their requesting the comprehensive ESTCP final report.

The products are listed in order of expected level of customer time commitment for review of the material.

Pocket Card: A double sided 9” X 4” high quality printed card briefly describing the technology with point of contact details. The Pocket card has proven to be the preferred media format for customers collecting material from booths at a conference venue. Pocket cards are less bulky and are less of an inconvenience when transporting product information home along with other organizations’ material.

Technology Briefing Slide: A briefing slide is often used with other briefing slides of individual technologies to create a presentation. By having the slides on hand, it allows for a presenter to quickly arrange them into a presentation catering to a specific focus at a moment’s notice. These presentations are typically given to higher level personnel as representative of a DoD organization’s or RDT&E program’s current efforts and accomplishments. Slides will typically give a brief description of the technology, what need it addresses, benefits, cost figures and POC information.

Poster: A single sided large scale product designed to be used at conference settings, open house presentations, demonstration site kiosks and on occasion used in email communication as an attachment.

Technology Data /Fact Sheet: A double sided letter sized high quality printed card stock product used to hand out or referred to as an information product posted on a command website. The technology data sheet bridges the gap from a video or pocket card leading to a request for the

highly detailed final report The technology data sheet has been particularly successful in peaking interest when linked in a targeted email communication and when sent after engaging stakeholders by phone and conference call.

Five Minute Video: A product that show-cases the technology developer describing their technology, visual diagrams, footage of the technology shown in operation, and positive testimonial from a satisfied customer. The product is usually posted to a web site and referred to via email or by a transmitted document. It is not typically handed out in a DVD form, but can be if determined to be advantageous. The video product is similar to a T.V. commercial for both format and promoting a positive response by the potential viewer/customer to take action to seek additional detailed information concerning the subject technology. The video has been successful in peaking interest when linked in a targeted email communication and when sent after engaging stakeholders by phone and conference call. Application of the video product is currently being considered at demonstration site kiosks and at command entrance settings. Efforts to use the existing TTRWW video to engage both customer and funding program managers have resulted in the intended response actions.

Recorded Webinar: A narrated presentation providing detailed information in a PowerPoint format. A typical webinar will run between 10 to 20 minutes in length. Recorded webinars provide detailed information in a relatively short period of time. The webinar is a tool that allows interested parties to convince their superiors of the merits of a technology

Journal/Magazine Article: A multi-page product providing detailed information of a technology. It often includes more than one photo or diagram of the technology's application at a DoD site. Typically it will describe a site demonstration of a technology with the relevant data/results collected during the demonstration and provide a conclusion concerning its value to the DoD. A journal article is often used as the most in-depth technology transfer product next to the ESTCP final report.

Industry Criteria/Standards: Industry standards are published by organizations such as the National institute of Building Sciences in the form of a United Facilities Criteria (UFC). The UFC's are documents that provide planning, design, construction, sustainment, restoration, and modernization criteria to the Military Departments, the Defense Agencies, and the DoD Field Activities. To incorporate a technology or classification of technology into an industry criteria or standard, the transfer specialist must apply through the proper organizational channels for it to be considered for adoption. In the case of a UFC, forms such as the UFC Coordination Sheet must be signed off by the proper NAVFAC personnel and be presented to the assigned Discipline Working Group for final approval. Establishment of criteria incorporating a technology provides the perspective customer an added level of confidence that the technology is approved for use by those considered the expert authority.

Acquisition package: A compiled set of example forms, documents, checklists, drawings and guidance designed to help the perspective customer acquire the technology. A package such as this is often overlooked, but can be instrumental in the successful acquisition of a technology once the customer makes the decision to purchase the product. Typical documents include examples of SOWs, IGEs, available contract options, partnership agreements, necessary permits, work safety

plans, construction drawings, scheduling, necessary personnel, example DD 1391 forms, and Industry criteria.

When engaging the customer, the end-goal for the technology transfer specialist is the customer's acquisition of the technology. However, the technology transfer specialist is also obligated to ask customers for information identifying stakeholders, POCs and venues that would lead to further success. For example, the technology transfer specialist may ask; does the customer belong to a community of narrowly focused end-users and stakeholders as it relates to the subject technology, does the customer participate in scheduled meetings with their community, and/or do they participate in a unique seminar, workshop or training event specific to their community. If so, the technology transfer specialist would then be given the opportunity to ask organizers of such activities to present at their event. Presenting at events with narrowly focused subject matter, as opposed to large conference venues, has shown to produce a greater level of attendee interest, leading to a greater level for T2 leads and success.

Successful Technology Transfer

Actual technology acquisition and secured funding will be considered the primary goal and the metric as a determination of success. A secondary metric would involve the determination of the prospective customers, who express a high level of interest in acquiring the technology, but are unable to securing funding. A tertiary metric for success are the number of prospective customers requesting review of the technology's final report.

The proposed funding options will be evaluated to determine in what situations a specific funding and contractual approach would be the preferred choice and how the acquisition package would reflect the criteria to make that choice.

Funding should be sought from both DoD acquisition programs and non-traditional sources, such as state grant programs to implement the smart irrigation technology at one or more sites. Water projects, such as smart water irrigation, that are not funded locally can be funded through private sector financing from Energy Savings Performance Contracts (ESPC), Energy Conservation Investment Program (ECIP), MILCON and SRM. A project payback under ten years can justify Energy Program funding.

Appendix J: Fort Hood Demonstration

SMART WATER CONSERVATIONS SYSTEMS

FOR IRRIGATED LANDSCAPES

AT

U.S. ARMY FORT HOOD BUILDING 4612
KILLEEN, TX

Smart Water Conservation Systems for Irrigated Landscapes

1. General Description. The Smart Water Conservation Systems for Irrigated Landscapes project at Fort Hood consists of suites of commercially available technologies, controls and water piping that provides lawn irrigation to a one of the five lawn irrigation zones at the north end of Building 4612. The system controller measures the moisture content of this zone and adjusts the watering interval to maintain soil moisture above a minimum selected value. A second zone of approximately equal area was selected for comparison purposes, and was irrigated using the existing time-based watering schedule. The water used by this zone is measured and compared to the moisture-based watering schedule to document the water saving ability of using moisture base irrigation.

To further decrease potable water usage, a rainwater collection system is installed that collects the rainwater runoff from a portion of the roof of building 4612. The rain from approximately 5,000 square feet of roof was collected, filtered and supplied to a 10,000-gallon harvest water tank. This above ground tank provides the water used to irrigate the moisture-based zone. In addition to the rainwater collected, condensate from four HVAC air handlers was collected and supplied to the harvest water tank. If the rainwater and condensate contributions to the harvest water tank are not sufficient to supply the irrigation needs for the moisture-base plot, additional minimum amounts of potable water (make-up water) are supplied to the harvest water tank.

An electric driven pump, drawing water from the harvest water tank, is used to supply water to the turf area with the moisture-based sensor. The interval between watering cycles and the duration of the cycle was determined by the controller based on the zone soil moisture, and the settings of the controller established by the project manager.

2. System Description. The following paragraphs provide a detailed description of the composition and functioning of the systems and controls for the Smart Water Conservation Systems for Irrigated Landscapes project at building 4612.

a. **Rainwater Collection System.** Rainwater runoff from a portion of the roof at the northwest corner of building 4612 was collected and directed to the Harvest Water Tank. The rain runoff from approximately 5,000 square feet of roof drops into the rain gutter installed at the edge of the roof. The current rain gutter was modified by installing 3-inch high dams in each downspout, thereby preventing rain from draining from the gutter until the water depth exceeds 3-inches. A new downspout, installed without a dam, allows water to flow from the rain gutter down and into a Coanda type filter. The Coanda filter consists of a machined inclined screen which operates on the principle of the Coanda effect. This screen, installed at an angle to the water flow, allows any debris or heavy solids to slide down the screen without mechanical clearing, and fall through an opening to the ground.

   The cleaned rain water passes through the filter screen and continues down and out of the filter. This water was directed to the First Flush System and to the Harvest Water Tank.

b. First Flush System. The purpose of the First Flush System is to discard an initial amount of rainwater runoff from the roof. This runoff will typically contain granular roof particulates, dirt, leaves, and bird residue. Directing this water to the First Flush Barrel prevents dirt and residue from accumulating in the Harvest Water Tank. The system consists of vertical piping from the rainwater filter to the first flush barrel. In the vertical line is installed a tee and horizontal piping leading to the harvest water tank. At the beginning of a rain storm, water will flow from the filter and begin to fill the barrel. Once the barrel is full, water will back up the pipe to the tee. Additional water will then be forced to flow through the horizontal line over to the harvest water tank. The first flush barrel was equipped with a weep hole mounted near the bottom of the barrel. This fitting will allow a small amount of water to leak from the barrel, causing it to empty over a period of approximately 24-hours. This allows the barrel to be ready to accept the first portion of the rainwater when the next rainfall occurs.

c. HVAC Condensate Collection System. Condensate collected from two HVAC air handlers in the south mechanical room was directed to the tank of a self-contained condensate pumping unit. When the tank fills, a pump in the unit will pump the condensate, through a check valve, via installed tubing to the north mechanical room. There, another condensate pump unit was installed that collects condensate from two HVAC air handlers. The output from this unit passes through a check valve and connects with the output from the south mechanical room unit before being directed through a flowmeter and to the harvest water tank. The flowmeter, connected to the system controller, will provide an indication of the flow in total gallons of HVAC Condensate entering the harvest water tank.

d. Make-Up Water Addition System. If rainwater collected from the roof and condensate from the HVAC air handlers is insufficient to provide the needs of the irrigation system, additional potable water was obtained via the make-up water addition system. This system consists of piping connected to the potable water supply (after a backflow preventer) and a flow control valve/flowmeter. When directed by the system controller, due to a low level indication in the harvest water tank, the flow control valve/flowmeter opens allowing potable water to flow into the harvest water tank. The flowmeter, incorporated into the control valve, was connected to the system controller and provides an indication of the flow and total gallons of make-up water entering the harvest water tank.

e. Harvest Water Tank. The harvest water tank is the collection point for roof rainwater run-off and HVAC air handler condensate. The 10,000- gallon tank, installed above ground on a concrete base, was modular, constructed on site, and uses a circular galvanized steel shell. A multi-layer polyolefin/polyethylene liner was installed within the outer shell followed by a galvanized steel roof. The tank was designed for a 90 mile-per-hour wind load.

All water sources (rainwater, condensate or make-up) entering the tank will enter through the roof via a removable debris catchment filter. The filter serves to prevent any build-up of organic waste at the bottom of the tank, and prevent mosquitoes and other insects from entering the tank. All piping for fluids entering the tank was configured to provide ease of filter removal and cleaning. The tank roof was

equipped with a lockable hatch providing entry to the tank interior and a removable ladder to provide access to the roof hatch. The ladder can be relocated to provide access to the interior of the tank. A 6-inch tank water overflow was provided that directs excess water to the ground level. The end of this overflow was equipped with a flapper to prevent mosquitoes and other insects from entering the tank. A tank drain, located at the center of the tank provides a means of draining and flushing the tank as required. A manual ball valve was located underground, accessible from a valve box located 2 feet north of the overflow flapper.

The tank drainage piping was connected to the adjacent below ground drainage culvert.

The tank was provided with two outlet ports located near the bottom of the tank. One port provides water to the irrigation pump while the other port provides a connection for the harvest water tank overflow valve.

f. Harvest Water Tank Controls and Sensors. The harvest water tank was equipped with a series of controls and sensors which provide input to various system components.

i. Tank Liquid Level Switch. A float operated, three operating level, reed type liquid level switch, was installed in the roof of the harvest water tank. The three switches provide the following functions:

- **Level 1 – Irrigation Pump Control (Switch #1).** This switch, located at approximately 12-inches from the tank bottom, will disable the irrigation pump if the water level falls below this value.
- **Level 2 – Make-Up Water Control (Switch #2).** This switch, located at approximately 16-inches from the tank bottom, will provide a signal to the system controller to turn on the make- up water addition system. When the tank water level rises approximately one half inch, the make-up water addition system will turn off.
- **Level 3 – Overflow Drain Valve Control (Switch #3).** This s witch, located at approximately 76-inches from the tank bottom, will open the tank overflow drain valve. When the tank level drops approximately one half inch, the overflow drain valve will close. (Note! This overflow drain valve control was disabled at the conclusion of the demonstration period as it proved unreliable. The control was only needed to measure the volume of water exiting the tank during rain events and is not required for normal operations. Overflow will exit through the tank's standard 6-inch overflow pipe.)

ii. **Overflow Control System.** The function of the harvest water tank overflow control system was to measure overflow resulting from excess rain or condensate. To prevent water from overflowing through the water tank's standard 6-inch overflow pipe, a drain system consisting of a connection at the bottom of the tank, a flowmeter, and an electric motor operated ball valve was installed. When the tank water level reaches approximately 76-inches, the tank level switch will cause the motor operated valve to open. Water will flow through the flowmeter,

the electric motor operated valve, and down through underground piping leading to the adjacent drainage culvert. The valve returns to closed position when the water in the tank recedes back to 76-inches. The flowmeter, connected to the system controller, totalizes the volume of water leaving the harvest water tank.

iii. Harvest Water Tank Level Indication. A series of five moisture sensors, mounted vertically, are mounted within the harvest water tank. Together they provide an indication of tank water level. The sensors are connected to the irrigation system controller. They are designed to measure average soil moisture over their entire sensing surface and will in this case provide readout of 0% to 34% moisture dependent on the percentage of the surface that was covered by water. A chart is provided at the end of this section as a convenience to convert the sensors readout into tank level in inches and gallons of stored water.

g. Irrigation Water Pump. A one horsepower electrically-driven water pump was installed to draw water from the harvest water tank and send it to the Demonstration Smart Plot for irrigation. The pump provides approximately 18 gallons-per-minute at an output pressure of 40-psi. The pump was controlled by the system irrigation controller and only operates when irrigation was required based on pre-established soil moisture setting. Immediately downstream of the pump is a water filter containing a 155-mesh cleanable filter element. To prevent damage, the irrigation water pump will be disabled anytime the level in the harvest water tank falls below approximately 12-inches, the level of switch #1 of the tank liquid level switch.

h. Demonstration Plot. The demonstration plot consists of one irrigation zone, and was located at the eastern end of the lawn area to the north of building 4612. A moisture sensor, installed near the center of this area, was connected to the system controller and forms the basis for determining the watering schedule. When the controller determines that the moisture level has dropped below the threshold set into the controller, the controller turns on the irrigation pump and opens the demonstration plot flow control valve. Water from the harvest water tank was pumped through the filter, through the flow control valve (where flow will be measured), and through efficient sprinkler heads installed at the demonstration plot. Watering continues until the end of the watering cycle. The flowmeter, incorporated into the control valve, was connected to the system controller and provides an indication of the flow and total gallons of water that was sent to the demonstration plot.

i. Benchmark Plot. The Benchmark Plot or Control Plot is an irrigation zone, consisting of an area approximately the same as the demonstration plot. This plot was irrigated using potable water, based on the existing time-based irrigation control. A flowmeter installed on the potable water line measured the water used for this zone, and provided a means of comparison of water usage between the demonstration plot and the benchmark plot. The flowmeter was connected to the system controller and provides an indication of the flow and the total gallons used.

j. System Controller. The system controller was a Baseline Systems, Inc., series 3200 irrigation system controller. This controller provides both the ability to operate the irrigation system for the demonstration plot, and the ability to monitor and record data on the remainder of the system.

Specifically, the controller:

- Monitors and records the soil moisture levels for the demonstration plot
- Controls the water flow to and measures the total water used by the demonstration plot
- Based on soil moisture conditions, determines when irrigation of the demonstration plot needs to occur
- Controls operation of the irrigation pump
- Measures water total water usage by the benchmark plot
- Controls the water flow and measures the Harvest Water Tank make-up usage
- Measures the total HVAC condensate entering the harvest water tank
- Measures the harvest water tank overflow
- Provides an indication of the water level in the harvest water tank.
- Records system flow, water usage, and moisture data and provides reports showing this data via remote monitoring software

k. Bi-Coders. Bi-Coders are Baseline's term for several types of two-wire devices. A Baseline valve decoder is referred to as a valve Bi-Coder. Baseline decoders are called Bi-Coders because they are capable of full, bi-directional communications, which enables Bi-Coders to report back to the controller with specific information, including valve solenoid current and voltage, two-wire communications health and voltage, and other diagnostics information. Each Bi-Coder has a unique address that allows the controller to communicate with specific devices. In some cases the Bi-Coder was built into the device (moisture sensor, event bi-coder, pump start relay, in-line flowmeters, etc.), in other cases the bi-coder was a stand-alone unit that was connected by external wiring to the device (flow control valve/flowmeter).

l. Two-Wire Path. The following devices communicate with the controller via the two-wire path:

- Demonstration Plot Moisture Sensor
- Demonstration Plot Control Valve/Flowmeter
- Benchmark Plot Flowmeter
- Make-Up Water Control Valve/Flowmeter
- Harvest Water Tank Overflow Flowmeter
- HVAC Condensate Flowmeter
- Harvest Water Tank Level Indication Moisture Sensors
- Pump Start Relay Bi-Coder for Irrigation Pump

- Event Bi-Coder monitoring the make-up control level switch

In addition to the items above, a lightning arrestor was installed at the end of the two-wire path to provide enhanced protection to the buried two-wire path from the induced effects of a close-by lightning strike. The path provides two-way communications between the controller and the device. The controller may send a control signal to a device (such as a Control Valve/Flowmeter) to tell it to turn on or off, or the device may send data back to the controller (such as the flow rate and total gallons of water that have flowed through a Control Valve/Flowmeter). In addition, the controller can send limited self-test signals to the devices to have them self-diagnose potential problems.

Device	**Bi-Coder ID**	**Function**
Demo Plot Moisture Sensor	SB06520	Measure Demo Plot Soil Moisture
Demo Plot Control Valve/Flow Meter	WMV0698	Control Water to Demo Plot/Measure Gallons Used
Benchmark Plot Flow Meter	PFS0659	Measure Water Flow/Gallons to Benchmark Plot
Makeup Water Control Valve/Flow Meter	WMV0820	Control Water Flow to Harvest Tank/Measure Gallons Used
Harvest Tank Overflow Flow Meter	PFS0675	Measure Tank Overflow Gallons Drained
Condensate Flow Meter	PFS0672	Measure Condensate Flow/Gallons to Tank
Pump Start Relay Bi- Coder	PR00253	Control Operation of the Water Pump
Potable Water Make-Up Control Level Switch	RP00450	Control Operation of Potable Water Make-Up Control Valve
Harvest Water Overflow Control Level Switch	RP00439	Control Operation of Tank Overflow Control Valve
Cell Modem Information	SIM ID: 8901-4103-2556-8252-8402	Cell Modem S/N: CMX-1305225
Tank Level Indication Moisture Sensor	SB07315	Tank Level Indication 66.8” – 82.5”
Tank Level Indication Moisture Sensor	SB07320	Tank Level Indication 51.8” – 67.5”
Tank Level Indication Moisture Sensor	SB07530	Tank Level Indication 36.8” – 52.5”
Tank Level Indication Moisture Sensor	SB07532	Tank Level Indication 21.8” – 37.5”
Tank Level Indication Moisture Sensor	SB07607	Tank Level Indication 6.8” – 22.5”

Lessons Learned

SYSTEM DESIGN	
Issue	Response/Lesson Learned
Irrigation valve (manufactured by Netafim and known as "hydrometer" is a combined flow meter and bi-coder valve) did not completely close due to low pressure exerted by tank water level during non-irrigation hours. Consequently harvested water and potable make-up water was lost through this valve when irrigation pump was off. (Manufacturer's technical representative was unaware that there is minimum pressure requirement to prevent leakage).	Specify/install an adjustable spring-loaded check valve between the irrigation pump and the irrigation valve to eliminate leakage under low pressure conditions. (Irrigation valves require minimum operating pressure to positively seat diaphragm, which prevents leakage. The minimum static pressure was not achieved because tank water levels were less than 10 feet in the selected low profile tank.) Adjust break point on spring loaded check valve to unseat at pressures exceeding high water level conditions. The adjustable check valve used in the demonstration did not reduce pump pressure appreciably.
Simple mechanical ball check valve failed causing erratic condensate flow measurements.	All mechanical equipment has the potential for failure. Procure high quality equipment to best meet conditions encountered with field demonstrations.
Rainwater from the roof was collected in the harvest tank but at lower volumes than expected. Existing downspout and gutter system was retrofitted with check dams at existing downspout inlets to divert water to a single downspout above the harvest tank. The concept seemed adequate, but too much water was lost to existing downspouts. Leaves from a nearby tree may have clogged the check dam bypass, preventing rainwater from entering the downspout to the harvest tank.	Existing gutters and downspouts should be replaced with a new gutter and downspout system to direct the majority of the runoff through one downspout to feed the harvest tank. Also, install gutter guard screens to prevent leaves from entering gutter and clogging entrance to downspout.
Baseline Controller system failed to maintain irrigation schedule changes, and repeatedly reverting back to original settings. Two programming changes were required during the demonstration. Front panel display also failed, resulting in data loss.	The cause of the controller failure was not specifically identified. Power supply adequacy and surge protection design for Baseline Controller system may have contributed to this failure.
Bicoders on the Netafim "hydrometer" combined flow meter-valve failed, resulting in loss of valve functionality and data collection. Three failures occurred during the data collection phase.	The cause of the bicoder failure was not specifically identified. Power supply adequacy along with installation of surge protection and lightning arrestor design may have contributed to this failure.
The Smart Water Conservation System, although not considered complex, requires a long term shake down period to be performed by on-site personnel. The shake down period	Plan for routine inspection and adjustment period to be conducted by on-site until reliable operation is observed.

identifies necessary adjustments and repairs during initial operation.	
Leakage and reliability issues from installation of overflow outlet located at bottom of harvest tank.	Design overflow outlet location at top of harvest tank.
The Coanda filter plumbing resulted in rain water bypass of the collection tank under low flow conditions.	The plumbing leading to the Coanda filter inlet needs to be a straight length of pipe at least 5 to 10 time the pipe diameter to collect water under low flow conditions.
Above ground irrigation pump operated satisfactorily throughout the demonstration period.	Consider flow and system requirements when selecting alternative pump locations.

Study Limitations
Performance Objectives could not be satisfactorily assessed due to multiple instrumentation and equipment failures, preventing acquisition of consistent and defendable data. In addition, Fort Hood DPW did not irrigate the control plot during the demonstration period due to water restrictions triggered by the 5th year of drought in Texas. As a result of these data gaps, a proper assessment could not be performed.
Instrumentation problems with the overflow metering system caused significant loss of captured rain water attributable to malfunctioning electrical relays. For purposes of this demonstration rainwater overflow was measured out of a pipeline exiting the bottom of the tank. The pipeline was configured with flow meter and electrically actuated ball valve controlled by high water level float sensor. The reason for this design was to acquire a uniform flow under constant pressure head that can be achieved with a bottom exit port. Unfortunately the tank high level sensor which triggers valve close or open failed during major storm events. The valve failed in the open position which caused complete loss of water. Future demonstration should consider use of fail close valve regardless of the expense to ensure quality and completeness of flow data for assessment of system performance. In retrospect it would have been better to capture the overflow from the standard tank overflow port at the top of the tank and pump through a flow meter to measure volume. The bottom overflow port designed for the demonstration was disabled at the conclusion of the study, and overflow now exits via top of tank.

Appendix K: Rainwater Capture System Winterization Plans

WINTERIZATION OF SMART WATER IRRIGATION SYSTEM – BLDG 4612

To winterize the smart water technologies irrigation system, the following procedures should be followed.

Secure the HVAC Condensate System:

1. In the mechanical room located at the **South** end of building 4612, locate the condensate transfer pump on the floor beneath the air handlers. Unplug the electric power cord (see Figure 1).
2. In the mechanical room located at the **North** end of building 4612, locate the condensate transfer pump on the floor beneath the air handlers. Unplug the electric power cord (see Figure 2)

Figure 1

Figure 2

Note: When the condensate pump units are disabled, any condensate flowing from the air handlers will be safely discharged to drain.

Disable irrigation system operation:

3. Open the irrigation controller cabinet (see Figure 3) and move the system control knob to the OFF position. This will disable irrigation system operation, while allowing remote viewing of system parameters.

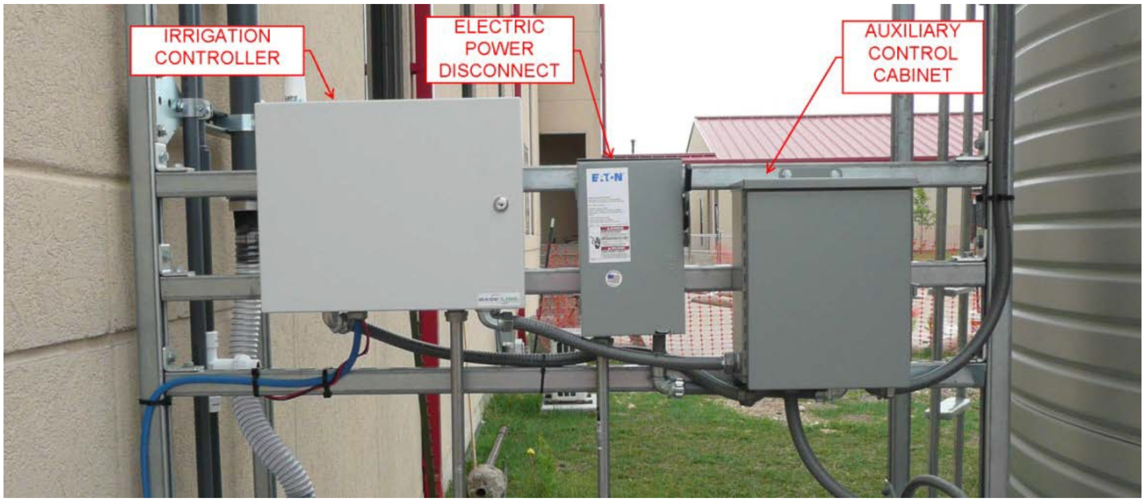


Figure 3

Secure make-up water:

4. Locate the Make-Up Water Isolation Valve in the valve box (see Figure 4 & 5). After closing the valve, remove adjacent drain plug. Allow all water to drain, and then reinstall the pipe plug.

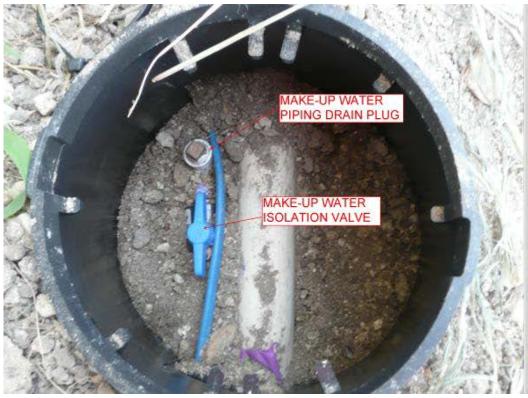


Figure 4 Figure 5

Drain harvest water tank (optional):

5. Drain all water from the Harvest Water Tank. Open the water tank drain valve box cover to expose the drain valve (see Figure 6). Rotate the valve handle 90° counter- clockwise. After a few seconds, water should become visible flowing in the nearby concrete drainage channel. Leave valve in the open position.

Figure 6

Drain first flush piping (optional):

6. Loosen the clamp and disconnect the lower connection of the flexible hose leading to the First Flush Barrel (see Figure 7). Install the clamp over the flex hose and tighten until snug. Redirect water to properly drain away from building to nearby storm water culvert.

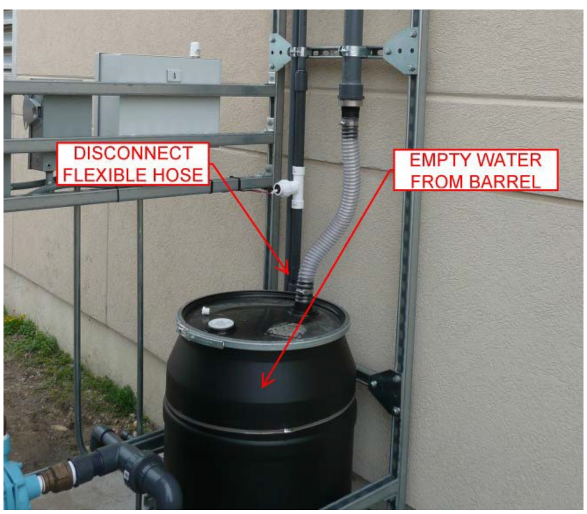


Figure 7

7. Remove the white weep fitting at the bottom of the first-flush barrel (see Figure 8). Flush any debris and save the fitting in the Auxiliary control cabinet.

Figure 8

Drain Irrigation Pump and Irrigation Piping (if the water tank has been drained):

8. If the harvest water tank HAS BEEN drained:

a. Verify that the ball valve on the line leading from the Harvest Water Tank to the Irrigation Pump is OPEN.

b. Remove the ¼" drain plug near the bottom of the Irrigation Pump housing (see Figure 9).

c. Drain the water from the pump inlet hose by disconnecting the pump end of the hose at the brass swivel on the upper end of the hose (see Figure 9). After lowering the hose to allow all water to drain reconnect the hose.

9. If the harvest water tank HAS NOT BEEN drained:

a. Verify that the ball valve on the line leading from the Harvest Water Tank to the Irrigation Pump is CLOSED.

b. Remove the ¼" drain plug near the bottom of the Irrigation Pump housing (see Figure 9).

c. Drain the water from the pump inlet hose by disconnecting the pump end of the hose at the brass swivel on the upper end of the hose (see Figure 9). After lowering the hose to allow all water to drain reconnect the hose.

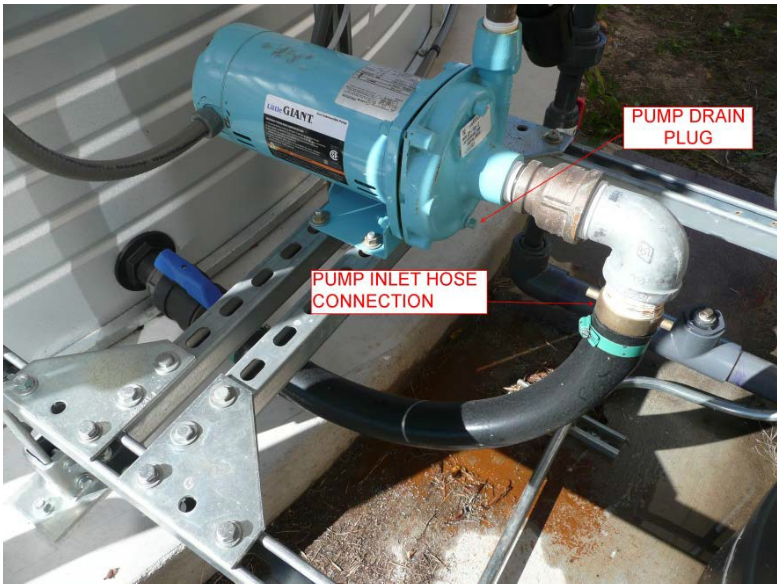


Figure 9

10. Remove ½" pipe plug from the tee on the 2" irrigation water line (see Figure 10).

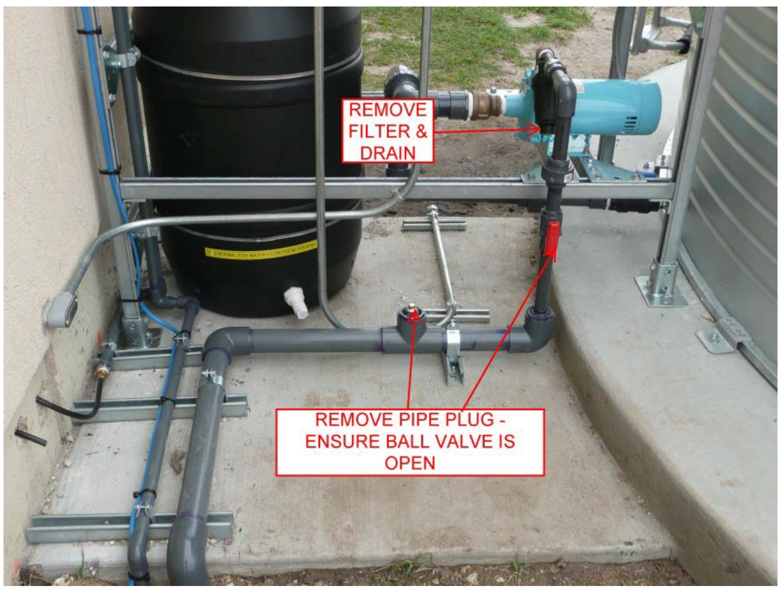


Figure 10

11. Remove the filter element from the water filter housing on the discharge of the water pump. Clean the element to remove any contaminants. Reinstall the filter element in the filter housing.
12. Ensure the ball valve downstream of the water filter is OPEN.
13. Locate the Demo Plot Zone Control Valve (see Figure 11) near the flag pole. On the side of the valve, locate the water pressure tap fitting (see Figure 12).

Figure 11

Figure 12

14. Loosen the tubing fitting and pull the black tubing from the tap fitting. Allow all water to drain from the tap fitting.
15. When all water has drained, reinstall the tubing and hand tighten the tubing nut.

Drain HVAC Condensate Piping:

16. Remove the pipe plug from the condensate piping (see Figure 13). Allow all water to drain form piping, then reinstall pipe plug.

Figure 13

PLACING SMART WATER IRRIGATION SYSTEM INTO OPERATION – BLDG 4612

To place the smart water irrigation system into operation after winterization procedures have been carried out follow the step below:

Reestablish HVAC Condensate Collection:

1. In the South Mechanical Room plug in the electric power cord of the condensate transfers pump (see Figure 14).
2. In the North Mechanical Room plug in the electric power cord of the condensate transfers pump (see Figure 15).

Figure 14


Figure 15

Enable Irrigation System Operation:

3. Open the irrigation controller cabinet (see Figure 16) and move the system control knob to the RUN position. This will enable irrigation system operation.

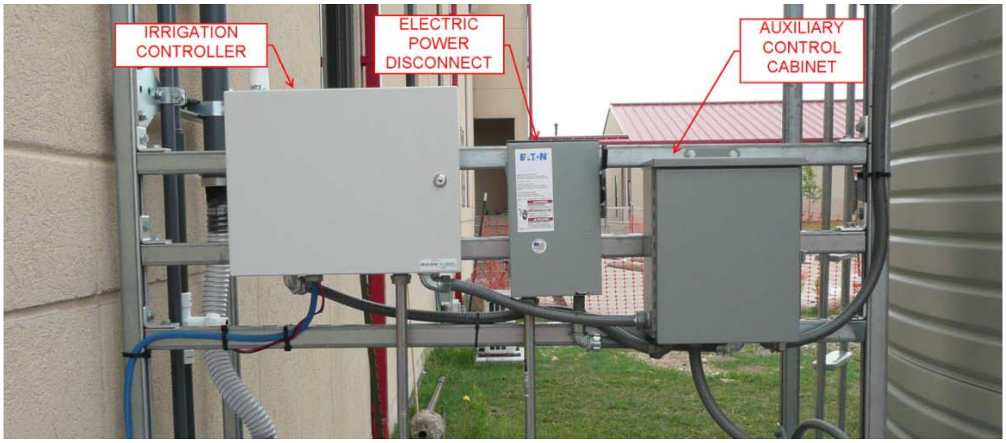


Figure 16

Enable make-up water:

4. Locate and open the Make-Up Water Isolation Valve in the valve box (see Figures 17 & 18).

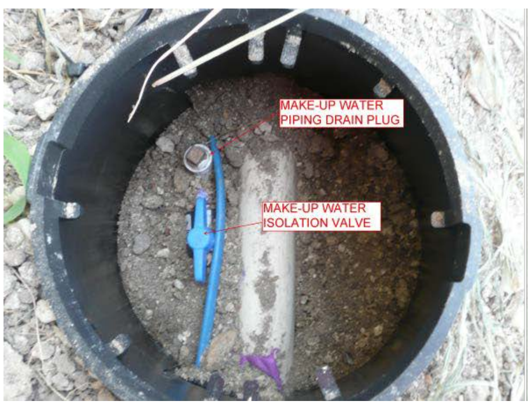


Figure 17

Figure 18

Harvest Water Tank:

5. If the harvest water tank has been drained open the water tank drain valve box cover to expose the drain valve (see Figure 19). Rotate the valve handle 90° clockwise to close the valve.

Figure 19

First Flush Piping:

6. At the first flush barrel, loosen the clamp on the free end of the flexible hose and connect it to the hose barb on the first flush barrel, then tighten clamp till snug.
7. Ensure the white weep is installed in the bottom of the first flush barrel (see Figure 20).

Figure 20

Irrigation Pump and Irrigation Piping:

8. Open the ball valve on the line leading from the Harvest Water Tank to the Irrigation Pump.
9. Open the ball valve downstream of the water filter.

Appendix L: Points of Contact

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